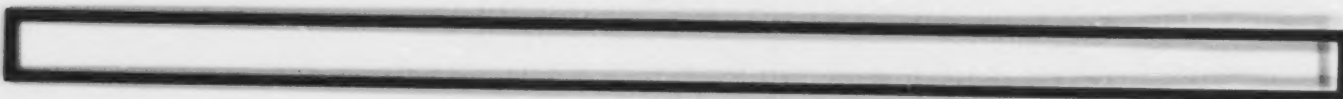


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Carbofuran: Technical Support Document
Special Review

(U.S.) Environmental Protection Agency
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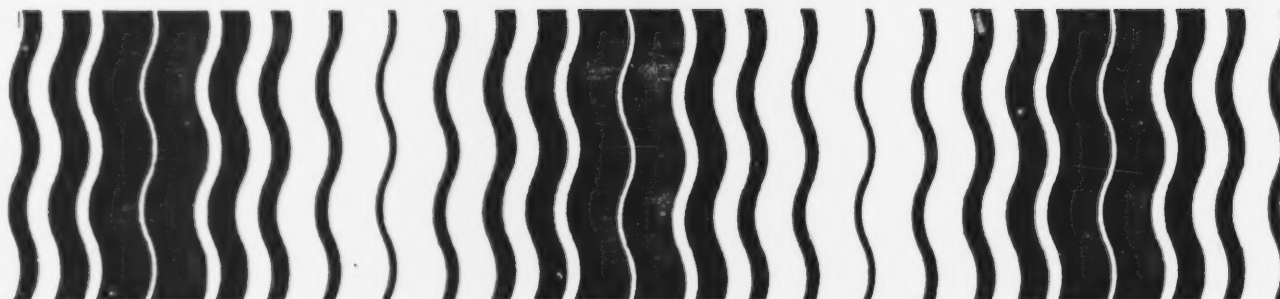


CARBOFURAN

SPECIAL REVIEW

TECHNICAL SUPPORT

DOCUMENT



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EXECUTIVE SUMMARY

This Technical Support Document presents and describes the basis for the issuance of the Notice of Preliminary Determination proposing to cancel the registrations for all granular pesticide products that contain carbofuran as an active ingredient and are used on all sites. This proposed action is based on the Environmental Protection Agency (EPA or Agency) determination that the use of granular carbofuran generally causes unreasonable adverse effects to birds on all sites.

Carbofuran is a carbamate insecticide and nematicide that is generally applied as a prophylactic treatment when seeds are planted at the beginning of the growing season. Application is made to control pest problems that may or may not occur later in the season. Carbofuran may also be applied later in the season in certain cases.

Approximately 7 to 10 million pounds of active ingredient (lb ai) of all carbofuran formulations are used on a variety of agricultural crops and forestry sites per year, with approximately 6 to 9 million lb ai of the annual usage accounted for by the granular formulations. Sixty-eight percent of granular carbofuran use on corn, 14 percent on sorghum, 5 percent on soybeans, 2 percent on rice, 5 percent on peanuts, and 2 percent on tobacco. Also, less than 1 percent is used on each of the following sites: cotton, cranberries, sunflowers, and pine seed orchards. These uses encompass over 95 percent of the granular carbofuran usage and about 85 percent of all carbofuran formulation usage.

Carbofuran is formulated as a 2, 3, 5, 10, and 15 percent active ingredient granular product, but is also sold as flowable and wettable powder formulations. Granular carbofuran is classified as a restricted use pesticide based on avian toxicity.

EPA initiated a Special Review of granular formulations of carbofuran on September 30, 1985. At that time, the Agency determined that carbofuran granules are acutely toxic to birds and that acute poisoning may occur at most application sites. Because carbofuran is widely used, the Agency determined that large numbers of birds are potentially exposed and that population impacts could occur. The Agency solicited comments on its conclusions concerning the avian risk.

The Agency reviewed comments received and presents its revised risk assessment in this Technical Support Document. In assessing the risks to birds posed by the use of granular carbofuran, the Agency considered (1) laboratory data on acute avian toxicity, (2) exposure, (3) field studies, (4) estimated risk, (5) bird kill incidents, (6) population effects, and (7) toxicity of the alternatives.

Based on laboratory data, the Agency concluded that carbofuran is highly acutely toxic to birds, and that a single granule may kill a small bird. Birds, including endangered species, are expected to be present at the time of carbofuran application. Agricultural engineering and field studies confirm that at-planting application of granular pesticides, including carbofuran, results in granules exposed on the soil surface. Dietary exposure occurs from direct ingestion of granules and contaminated soil invertebrates such as earthworms. Predatory birds may be secondarily exposed to carbofuran by feeding on contaminated vertebrates such as small birds. Residues in wildlife confirm that both direct and secondary exposure to carbofuran has occurred.

The Agency assessed 6 field studies conducted at 11 locations in which the mortality of birds from the use of 10 and/or 15 percent granular formulations (10G and 15G) was investigated. Carbofuran was applied using band and in-furrow application, with the exception of one study in which 10G was applied using specialized equipment. All studies consistently resulted in bird mortality, regardless of application rate and when applied using commonly practiced techniques for soil incorporation of granules. Both direct and secondary poisonings occurred. The rates of mortality varied from 0.1 to 3.6 birds per acre. Studies demonstrate that bird mortality following the label-directed use of granular carbofuran can be considered a frequent and regular occurrence. Furthermore, the magnitude of the acute mortalities could be more heavily influenced by the numbers of birds entering treated fields, rather than by the extent of incorporation of granules or application rate.

Over 40 separate bird kill incidents involving one or more birds have been reported from direct carbofuran poisoning. These incidents occurred in several crops in various areas of the country and Canada. The types of birds varied and included both migratory and nonmigratory birds. Bird mortality was frequently associated with at-planting application, but has occurred with other uses at other times of the year.

Secondary poisoning incidents have also occurred and involved bald eagles, red-tailed hawks, red-shouldered hawks, northern harriers, and other birds of prey. Such species are attracted to dead and dying smaller birds and small mammals affected by granular carbofuran.

Such bird kill incidents are particularly troubling in light of the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act and the Endangered Species Act, which protect the taking of a number of bird species except by permit. More than 20 species of migratory birds and bald eagles protected by these Acts have been reported killed by carbofuran. In addition, the Fish and Wildlife Service has

determined that the continued survival of several endangered species is threatened by carbofuran use.

Birds of prey species commonly produce only a few young per year and are slow to reach sexual maturity. Thus, the death of each individual of these species can have important consequences for a population. A computer model of a small breeding population of bald eagles that had experienced several secondary mortalities due to granular carbofuran was used to illustrate this point. If the rate of carbofuran-related mortality observed in this population remains constant, the model predicted that the small breeding population will remain static over a 10-year span, even under ideal breeding conditions. At secondary mortality rates slightly higher than those observed in this population, the model predicted that the breeding numbers could decrease over the short span of the model.

The direct and secondary bird kill incidents that have been reported underestimate the number of incidents actually taking place because of the problems associated with the reporting of bird kills and with carcass removal by predators.

Populations of declining or endangered species may be present in areas where carbofuran is applied. The Agency cited documented population declines of the red-shouldered hawk, loggerhead shrike, field sparrow, Henslow's sparrow, and others. Statistically significant declines have been measured for several species.

While the Agency does not consider granular carbofuran to be the sole causative factor in the decline of the bird species discussed, carbofuran is one of the most highly toxic pesticides to which these birds are exposed. Given its high toxicity and its widespread use in agriculture, carbofuran is likely to be responsible for bird deaths in these species. The Agency concluded that granular carbofuran can, therefore, be an important additive factor in the declines. The granular formulations make it even more likely that birds of these species will be killed, because these birds can frequently encounter granules during their feeding activities, or in the case of raptors and other birds of prey, are killed through secondary poisoning.

The Division of Endangered Species and Habitat Conservation (DESHC) of the Fish and Wildlife Service indicated in its Biological Opinion for carbofuran that the Aplomado falcon, Attwater's greater prairie chicken, and Aleutian Canada goose were the bird species jeopardized by the use of carbofuran. To avoid jeopardy to these species, DESHC indicated that the use of carbofuran should be eliminated in certain areas. DESHC also indicated that the bald eagle, whooping crane, and Mississippi sandhill crane may be adversely affected and thus recommended prohibiting the use of carbofuran in certain areas.

The Agency compared the risks of granular carbofuran to avian species to the risks posed by its alternatives. Since the greatest risk of granular pesticides to avian wildlife may result from direct exposure, especially ingestion, the Agency compared the acute toxicity (in terms of number of granules equivalent to an LD50 dose) to the estimated exposure (in terms of number of granules exposed and available to birds per unit area) for carbofuran and its alternatives. Based on this comparison, carbofuran appears to generally pose a greater risk to birds than the alternatives.

The Agency evaluated information concerning the hazard to humans from carbofuran and some of its alternatives. Based on the available data, carbofuran does not appear to pose a chronic health hazard because it has not shown positive oncogenic, teratogenic, or reproductive effects. The data base is acceptable and is considered complete. Existing data indicate no adverse chronic health effects associated with any of the alternatives, although the data bases are incomplete so definitive conclusions cannot yet be drawn for all effects. The Agency has required that these data bases be completed. Based on data on acute health effects, the acute oral hazard of carbofuran is the same order of magnitude as fonophos, phorate, and terbufos, but less than aldicarb, and greater than the other alternatives evaluated.

The Agency also evaluated the potential for ground water contamination from carbofuran. The environmental fate data indicate that carbofuran is highly mobile and has a potential to leach. Simulation modeling supports this hypothesis. The environmental fate data indicate that under conditions of low pH and low temperature, residues of carbofuran could persist after leaching into ground water. Since these conditions are not widespread in the United States, most leaching of carbofuran will probably not result in significant concentrations at the wellhead. Monitoring information for Long Island, New York, Maryland, and Massachusetts show the highest and most frequently found residues in ground water. The highest level found was 71 parts per billion and was found in a well near corn and potato fields in Maryland. Concentrations above 36 parts per billion, the draft lifetime Health Advisory Level, will probably only occur in localized, worst-case situations. Other studies suggest that carbofuran could also be found in surface waters which may be used for drinking water. The Agency will be requiring improved revisions to ground water advisory statements currently on carbofuran product labels.

If carbofuran is not available for treatment of the 10 sites analyzed in detail, the Agency estimated an annual grower impact that ranged from approximately \$22.8 to \$33.0 million. The largest economic impact from cancellation of granular carbofuran would be for rice since no registered alternatives are available for control of the rice water

weevil. The Agency estimates the grower impact would be \$12.2 million annually; a \$6.1 million decrease in Federal deficiency payments to rice growers would indicate a net loss to society of \$6.1 million.

Corn is the major use site for carbofuran, and cost-effective, efficacious alternatives are available. No changes in costs of production, yields, or revenues would be expected. The corn insecticide market is highly competitive, and viable alternatives with similar pesticide performance are available at comparable cost per acre.

The carbofuran market for corn has been declining since 1978, and current usage is approximately one-third the level it was in 1978. Carbofuran has lost its market share primarily to terbufos and chlorpyrifos. By 1986, the market share held by carbofuran dropped to less than 15 percent, where in terms of acre treatments, it ranked fourth out of the five major corn insecticides. The reasons for the decline are not clear, but could include loss of effectiveness, spectrum of control, and others.

Carbofuran is applied to an estimated 185 acres of nonflooded cranberries in Washington and Oregon to control the black vine weevil. Because of the soil or the terrain of the fields, these cranberry acres are not diked for flooding. Carbofuran is one of two pesticides registered for black vine weevil control. The impact on cranberries is expected to occur over a 7-year period due to the perennial nature of the crop. Overall impacts could be approximately \$7 million to \$7.7 million over the 7 years or \$1.0 to \$1.1 million annually. This estimated impact does not consider the availability of the other pesticide.

For the U.S. sorghum industry, cancellation would generally not have an adverse effect on the overall sorghum industry (at most \$0.4 to \$0.9 million annually) or consumers. In years of high chinch bug infestations, which occur every 5 to 10 years, annual income reductions could range from \$7.4 to \$9.3 million if aldicarb is used as an at-planting alternative. However, this estimate of impact does not consider the foliar treatments that would be available for use when infestations actually occur. Foliar treatments may not always provide adequate control because of problems with treatment timing, limited availability of scouts, and chinch bug reinfestations.

For the remaining crops, the Agency does not anticipate major impacts. The overall economic impact from cancellation is not expected to result in significant changes in either production costs or outputs.

The Agency also evaluated aspects of carbofuran use that are not easily quantifiable. For example, if carbofuran was cancelled, only one carbamate pesticide (trimethacarb) would

be available for corn growers who rotate organophosphate and carbamate insecticides to delay development of resistance in soil pests. The Agency recognizes that some cross-resistance with organophosphates could occur because both affect acetylcholinesterase. Also, carbofuran has residual and systemic properties and a broad spectrum of control. It should be noted that repeated use of carbofuran may lead to an apparent increase in soil microbial populations that are capable of reducing its effectiveness.

In weighing the risks and benefits, the Agency reviewed a number of options other than cancellation to reduce the risk to birds. Among these measures were (1) additional precautionary labeling regarding the hazard to birds, (2) limiting carbofuran use to certain months of the year, (3) limiting application geographically, and (4) implementing a risk reduction program. The Agency evaluated these measures and determined that they would not adequately mitigate the risk to bring it into balance with the benefits.

As a result, the Agency is proposing to cancel granular carbofuran use on all sites. The decision to cancel granular carbofuran use is based on the conclusion that the risk to birds outweighs the benefits of use.

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I. INTRODUCTION

The Agency is examining the use of granular carbofuran because of its hazard to birds.

A. General Background and Organization

EPA is proposing regulatory action to reduce adverse effects from the use of granular carbofuran. The Agency evaluated the risk to birds based on (1) acute avian toxicity, (2) exposure, (3) field studies, (4) bird kill incidents, and (5) population effects. The benefits associated with the use of carbofuran were also evaluated.

This Technical Support Document contains several parts. Chapter I is this Introduction. Chapter II describes the hazard to birds resulting from granular carbofuran application to crops. Included in this Chapter are descriptions and evaluations of the risk information, an analysis of public comments pertaining to the avian hazard, and the Agency's conclusions. Chapter III contains a discussion and quantitative estimate of the benefits of granular carbofuran and describes the assumptions and limits of these estimates used to assess the benefits. A public comment analysis is also included. Chapter IV evaluates the human risks from carbofuran application. Chapter V describes the regulatory options considered by EPA to reduce the risk from carbofuran and evaluates the risks and benefits of these regulatory options. It concludes by summarizing the regulatory action that the Agency proposes to take. Chapter VI is the bibliography, which is followed by appendices.

B. Regulatory History

In 1984, the Agency issued a Guidance Document for the Reregistration of Pesticide Products Containing Carbofuran (Guidance Document) (U.S. Environmental Protection Agency 1984). This document indicated that carbofuran was highly toxic to wildlife, especially birds, and that field studies and use history strongly suggested that the use of carbofuran results in avian mortality and possibly local population reductions. Additional field studies were required to quantify the impact on avian populations.

The Agency considered initiating a Special Review at that time because of a potential problem with secondary poisoning of raptors. However, the Agency determined that the data were insufficient in this area to justify initiating a Special Review and that more data were needed to assess the impact of this potential problem on avian populations. As a result, the Agency required extensive multiyear monitoring of avian populations,

with special emphasis on raptorial birds in areas of heavy carbofuran use and in areas of early planting where high densities of wintering birds utilize treated fields. The decision on whether to proceed with a Special Review was withheld pending review of data.

In 1985 the Agency reevaluated its position regarding carbofuran and determined that the available data were sufficient to initiate a Special Review. As a result, the Agency initiated a Special Review of all granular carbofuran products on September 30, 1985 (50 FR 41938). As explained in the Position Document (PD) 1, the Agency determined that pesticide products containing granular carbofuran met or exceeded the then existing risk criterion for avian toxicity set forth in 40 CFR 162.11(a)(3)(i)(B) and in 40 CFR 162.11(a)(3)(ii)(c). The Agency also determined that granular carbofuran met or exceeded the then proposed risk criterion (50 FR 12195). The proposed risk criteria are now in effect as set forth in 40 CFR 154.7. Since carbofuran met or exceeded both sets of criteria, a Special Review would have been initiated regardless of which set of criteria were in effect. At that time, EPA also determined that data required by the Guidance Document were needed to refine the Agency's risk assessment.

C. Legal Background

1. The Statute

A pesticide product may be sold or distributed in the United States only if it is registered or exempt from registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended (7 U.S.C. 136 et seq.). Before a product can be registered unconditionally, it must be shown that it can be used without "unreasonable adverse effects on the environment" [FIFRA section 3(c)(5)]; that is, without causing "any unreasonable risk to man or the environment, taking into account the economic, social and environmental costs, and benefits of the use of the pesticide" [FIFRA section 2(bb)]. The burden of proving that a pesticide meets this standard for registration is at all times on the proponent of initial or continued registration. If at any time the Agency determines that a pesticide no longer meets this standard for registration the Administrator may initiate proceedings to cancel the registration under FIFRA section 6.

2. The Special Review Process

The term "Special Review" is the name now used for the process previously called the Rebuttable Presumption Against Registration (40 CFR Part 154).

The Special Review process provides a mechanism through which the Agency gathers risk and benefit information about pesticides that appear to pose risks of adverse effects to human health or the environment that may be unreasonable. Through issuance of various notices and Technical Support Documents, the Agency publicly sets forth its position and invites participation in the Agency's review of suspect pesticides by pesticide registrants, the U.S. Department of Interior, the U.S. Department of Agriculture, user groups, environmental groups, and other interested persons.

Risk evidence submitted to and/or gathered by the Agency must be evaluated and considered in light of benefit information. If the Agency determines that the risks appear to outweigh the benefits, the Agency can initiate action under FIFRA to cancel, suspend, and/or require modification of the terms and conditions of registration.

3. Additional Statutes

In considering this action under FIFRA, EPA is mindful of other statutes intended to protect birds. The Migratory Bird Treaty Act (MBTA) prohibits the taking, except by permit, of individual migratory birds (16 U.S.C. Section 703). Regulations promulgated pursuant to the MBTA list the migratory birds which are protected by the Act (50 C.F.R. Section 10.13). The MBTA prohibits unpermitted taking "by any means or in any manner" of the protected bird species. Case law holds that even unintentional kills of birds by pesticide poisoning is prohibited by the MBTA. More than 20 species of birds protected by the MBTA have been reported killed by carbofuran. Indeed, in one incident, a carbofuran manufacturer was convicted of violating the MBTA for causing the deaths of a number of birds exposed to a wastewater pond containing carbofuran.

A similar provision in the Bald and Golden Eagle Protection Act (BGEPA) prohibits takings of bald and golden eagles (U.S.C. §1538(c)). A number of bald eagle kills due to carbofuran have been reported (see section II of this document) and the U.S. Fish and Wildlife Service has determined that the continued survival of several endangered species is threatened by carbofuran use (see section II of this document). Taken together, the provisions of these three statutes prohibiting unpermitted bird kills underline society's concern with needless destruction of wildlife and provide additional support for EPA's proposed action on carbofuran.

D. Chemical Background

1. Chemical and Physical Characteristics

Carbofuran is the common name for 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate.

The trade names for carbofuran include, but are not limited to, Furadan, Curaterr, and Yaltox, although Furadan is the only name currently used.

Physically, technical carbofuran is a white C (pure material). Carbofuran is stable under neutral or acidic conditions and is unstable under alkaline conditions.

2. Registered Uses and Production

Carbofuran is a broad-spectrum insecticide and nematocide registered for control of pests on 27 agricultural crops and certain forest and pine seed orchard uses as follows:

Section 3 Registrations - cranberries, grapes (California only), bananas, plantains, cucurbits (cucumbers, melons, and pumpkin squash), peppers, potatoes, corn (sweet, field, and pop), sorghum, rice, sugarcane, tobacco, cotton, peanuts, sugar beets, sunflowers, soybeans, southern pine seed orchards, pine seedlings, Siberian elm, and cottonwood.

Special Local Need Registrations - apples, apricots, cherries, nectarines, peaches, plums, watermelon, garlic, alfalfa, barley wheat, rape, Christmas tree plantings, pine (Christmas tree), pine (plantation), southern pines, white pine (forest), and loblolly pine.

Agency records show 12 pesticide products are registered that contain carbofuran as the sole active ingredient (ai). These registrations are held by two registrants.

FMC Corporation, the major producer, holds 11 registrations. FMC formulates carbofuran as a 2, 3, 5, 10, and 15 percent ai granular product. These products include Furadan 2G, 3G, 5G, 10G, and 15G. FMC also markets a 4 lb ai per gallon flowable formulation; a 75 percent wettable powder; and 75, 85, and 90 percent ai formulation intermediates. At present, the technical is not federally registered.

International Spike, Inc. holds one registration of a spike product which contains 1 percent carbofuran and fertilizer which are compressed together to form a spike. This product is used on certain ornamental plants in interior landscaping.

All granular carbofuran products registered in the United States have been classified for restricted use based on the avian hazard. The flowable formulation is restricted based on its acute oral and inhalation toxicity to humans. The spike and intermediate formulations are unclassified.

II. ASSESSMENT OF AVIAN HAZARD

To evaluate the avian hazard from granular carbofuran use, EPA conducted a hazard assessment that considered carbofuran's acute toxicity, exposure, risk, field studies, bird kill incidents, population effects, toxicity and risk of the alternatives, and rebuttal comments. Data that led to the initiation of the Special Review were considered in the assessment. New data concerning bird kill incidents, agricultural practices, computer modeling, and bird surveys were also included. A list of the common and scientific names for birds mentioned in this hazard assessment are in Appendix 1.

A. Avian Acute Toxicity

Carbofuran is an acute toxin that inhibits cholinesterase and results in stimulation of the central, parasympathetic, and somatic motor systems. To evaluate the acute toxicity of carbofuran to bird species, EPA reviewed several acute toxicity studies using the technical grade of the active ingredient (Tucker and Crabtree 1970, Schafer et al. 1973, Schafer and Brunton 1979). These studies measured the median single lethal dose, which kills 50% of the test organisms (LD50). The LD50 is measured in milligrams per kilogram (mg/kg) of body weight of test species. Results of these studies are summarized below.

<u>Species</u>	<u>LD50 (mg/kg)</u>
Fulvous whistling-duck	0.24
Red-winged blackbird	0.42
Quelea	0.42
House sparrow	1.30
Common grackle	1.33
Rock dove	1.33
Coturnix quail	3.16
Ring-necked pheasant	4.15
Northern bobwhite	5.04
Starling	5.62

Two studies were also available that measured the LD50 for the mallard (Tucker and Crabtree 1970, Hudson et al. 1984). The results were as follows:

<u>Acute Oral LD50 (mg/kg) for the Mallard</u>	
Female 3 to 4 months old	0.40
Female 12 months old	0.51
Male 12 months old	0.48

The LD50 values indicate that carbofuran is very highly toxic to a variety of avian species. However, the degree of sensitivity of bird species varies. Among the species tested, the fulvous whistling-duck was the most sensitive and starlings were the

whistling-duck was the most sensitive and starlings were the least sensitive.

In addition, EPA evaluated a study (Balcomb et al. 1984b) that measured the toxicity of granules of carbofuran 10G. Two samples of carbofuran 10G were used. The study indicated that the consumption of a single granule may be fatal to a small bird. The following table summarizes the results from the administration of one and five granules.

Species	Number of Birds	Percent mortality	
		1 Granule	5 Granules
House sparrow	6	100	---
Red-winged blackbird	5	20	80

EPA estimated that only 0.455 of a 15G granule or 0.683 of a 10G granule may kill some small birds (U.S. Environmental Protection Agency 1987e).

Data concerning the subacute dietary dose (the median lethal dietary concentration that kills 50% of the test organisms or LC50) were also evaluated (Shellenberger and Gough 1972, Hill et al. 1975, Fink 1976a and b). The LC50 is measured in parts per million (ppm). The following table summarizes these studies, which tested technical carbofuran:

Avian Subacute Dietary LC50 (ppm)

Mallard	
5-7 days old	21
10 days old	190
14 days old	79
Northern bobwhite	
5-7 days old	158
14 days old	681
Japanese quail	
14 days old	438
Ring-necked pheasant	
10 days old	573

These LC50 values indicate that carbofuran is highly toxic to birds. The acute LD50 and LC50 toxicity studies also indicate that carbofuran can kill a bird within minutes.

B. Exposure

In assessing the risk from carbofuran, EPA determined whether birds would be present when carbofuran was applied and then investigated the possible routes of exposure. Birds may be

directly exposed by ingesting carbofuran granules or by feeding on invertebrates containing carbofuran residues. They may also be exposed by feeding on birds or other animals that are moribund or have already died from carbofuran and contain carbofuran granules/residues. Residues of carbofuran in birds confirm that exposure to carbofuran has occurred.

It should be noted that there is potential exposure of birds to granular formulations of carbofuran via routes other than direct ingestion of the granules or by feeding on food items contaminated with carbofuran. Birds may also be exposed to carbofuran through contaminated water. The principal means by which water may be contaminated is through (1) runoff into a farm pond or other body of water in proximity to a field treated with carbofuran and (2) formation of puddles, by either natural precipitation or irrigation, in a field after treatment with carbofuran. The most likely routes of exposure of birds to water contaminated with carbofuran is by bathing and drinking. Where contaminated water is present, there may be potential for significant exposure of birds to carbofuran. However, this condition (i.e., presence of contaminated water) will not always be met. Therefore, the discussion of exposure and resultant risk presented in this document will focus on the exposure resulting from the direct ingestion of carbofuran granules or food items contaminated with carbofuran.

1. Presence of Birds at Time of Application

EPA evaluated whether birds would be present during and immediately after the time that carbofuran is applied (U.S. Environmental Protection Agency 1987e and 1987g, Gussey and Maturgo 1972). This analysis was conducted for 10 use sites. Numerous bird species are expected to be present in each of these crops (Table II-1). The species listed include raptors (i.e., hawks, falcons, owls, etc.), upland gamebirds, waterfowl, and other taxa of birds). Many of these species were among those found killed by direct or secondary carbofuran poisoning, as reported in field study and or incident reports. In addition, most of these species are covered by the protection of the Migratory Bird Treaty Act.

EPA also expects that birds will be present in certain of the other use sites for which carbofuran is registered because these crops are generally grown in the same areas as the 10 use sites analyzed. Some of these use sites such as grapes are also attractive to birds.

Table II-1. Representative¹ bird species potentially exposed to carbofuran and summary of whether the species is listed in the Migratory Bird Treaty Act (MBTA) and Endangered Species Act (ESA) and whether there have been bird kills associated with field studies or incident reports. Y = Yes. J = jeopardized species and A = may be adversely affected according to ESA opinions concerning carbofuran.

	<u>Statutory Protection</u>		<u>Bird mortalities</u>	
	MBTA	ESA	Field Study	Incident report
<u>Wading birds</u>				
Great blue heron	Y			
Snowy egret	Y			
Little blue heron	Y			
Cattle egret	Y			
White ibis	Y			
Glossy ibis	Y			
<u>Waterfowl</u>				
Fulvous whistling-duck	Y			
Brant	Y			
Canada goose	Y			Y
-Aleutian Canada goose (subspecies)		Y, J		
Wood duck	Y			Y
Green-winged teal	Y			Y
American black duck	Y			
Mottled duck	Y			
Mallard	Y		Y	Y
Northern pintail	Y			Y
Blue-winged teal	Y			Y
Cinnamon teal	Y			Y
Northern shoveler	Y			
Gadwall	Y		Y	Y
American wigeon	Y			Y
Canvasback	Y			
Ring-necked duck	Y			
<u>Raptors</u>				
Black vulture	Y			
Turkey vulture	Y			
Mississippi kite	Y			
Bald eagle	Y	Y, A		Y
Northern harrier	Y		Y	Y
Sharp-shinned hawk	Y			
Cooper's hawk	Y			
Harris' hawk	Y			
Red-shouldered hawk	Y		Y	
Broad-winged hawk	Y			
Swainson's hawk	Y			
Red-tailed hawk	Y			Y
Rough-legged hawk	Y			
Golden eagle	Y			
American kestrel	Y			
Aplomado falcon	Y	Y, J		
Peregrine falcon	Y	Y		

Table II-1 continued

	Statutory Protection		Bird mortalities	
	MBTA	ESA	Field Study	Incident report
<u>Rails and allies</u>				
Black rail	Y			
Sora	Y			
Purple gallinule	Y			
American Coot	Y			Y
Sandhill crane	Y			
-Mississippi sandhill crane (subspecies)		Y,A		
Whooping crane	Y	Y,A		
<u>Shorebirds</u>				
Upland plover				
Killdeer	Y		Y	Y
Spotted sandpiper	Y			
Piping plover	Y	Y		
Semipalmated sandpiper	Y			
Pectoral sandpiper	Y			
Stilt sandpiper	Y			
Laughing gull	Y			
<u>Gamebirds</u>				
Greater prairie-chicken				
-Attwater's greater prairie-chicken (subspecies)		Y,J		
Sharp-tailed grouse				
Ruffed grouse				
Northern bobwhite				
California quail				
Mountain quail				
Ring-necked pheasant			Y	
Wild turkey				
Mourning dove	Y		Y	
White-winged dove	Y			
Common ground-dove	Y			
Common snipe				
American woodcock	Y			
<u>Owls</u>				
Common barn-owl	Y			
Eastern screech owl	Y			
Great horned owl	Y			
Barred owl	Y			
Long-eared owl	Y			
Great gray owl	Y			
Short-eared owl	Y		Y	
Northern saw-whet owl	Y			
<u>Nightjars</u>				
Whip-poor-will	Y			
<u>Woodpeckers</u>				
Red-headed woodpecker	Y			
Red-bellied woodpecker	Y			
Red-cockaded woodpecker	Y	Y		
Northern flicker	Y			

Table II-1 continued

	<u>Statutory Protection</u>		<u>Bird mortalities</u>	
	MBTA	ESA	Field Study	Incident report
<u>Songbirds</u>				
Eastern kingbird	Y		Y	
Horned lark	Y		Y	
Blue jay	Y		Y	Y
Scrub jay	Y			
American crow	Y			
Chihuahuan raven	Y			
Common raven	Y		Y	
Eastern bluebird	Y			Y
American robin	Y		Y	Y
Northern mockingbird	Y			
Brown thrasher	Y			
Loggerhead shrike	Y		Y	
Northern shrike	Y			
Starling	Y			
Northern cardinal	Y			
Pyrrhuloxia	Y			
Rose-breasted grosbeak	Y			
Blue grosbeak	Y			
Rufous-sided towhee	Y			
Lark bunting	Y			
Painted bunting	Y			
Indigo bunting	Y			
Field sparrow	Y			
Vesper sparrow	Y			
Lark sparrow	Y		Y	
Lark bunting	Y			
Savannah sparrow	Y		Y	Y
Grasshopper sparrow	Y		Y	
Henslow's sparrow	Y			
Cape Sable seaside sparrow				
Song sparrow	Y			
White-throated sparrow	Y			
Lincoln's sparrow	Y			
Lapland longspur	Y			Y
House sparrow				
White-breasted nuthatch	Y			
Tufted titmouse	Y			
Bobolink	Y			
Red-winged blackbird	Y		Y	
Tricolored blackbird	Y			
Eastern meadowlark	Y			
Western meadowlark	Y			
Yellow-headed blackbird	Y		Y	
Rusty blackbird	Y			
Brewer's blackbird	Y			
Boat-tailed grackle	Y			Y
Brown-headed cowbird	Y		Y	
Common grackle	Y			Y
American goldfinch	Y		Y	

¹ EPA examined bird occurrence for each of the sites for which granular carbofuran is registered. Most of the species listed in this table occur at many, if not all, of the sites. However, the purple gallinule and several of the waterfowl species generally occur only in rice.

The 10 use sites analyzed include corn, sorghum, soybeans, rice, peanuts, tobacco, cotton, sunflowers, pineseed orchards, and cranberries, representing 85% to 90% of all carbofuran usage and 95% of the granular uses of carbofuran. In general, carbofuran is applied as a prophylactic treatment at the beginning of the season to control pest problems that may or may not occur later in the season. Granules are applied when the seeds are planted (at-planting or preemergent application) from March through mid-July. Some treatments may occur later in the year after the plants have emerged (postemergent application). (For additional information concerning carbofuran application refer to Chapter III in this Technical Support Document.)

As most carbofuran is applied "at-plant", most sites are similar with respect to potential exposure to birds. That is, the habitat presented by the newly planted field will be bare ground, or in the case of minimum tillage systems, standing residues from the previous season's crop. Therefore, using the assumption that exposure is often comparable among sites, the resultant risk to birds will also be comparable. For example, at-plant application of carbofuran to corn at the 1 pound of active ingredient per acre using the in-furrow application method should result in similar risk to birds as application to soybeans for the same conditions.

The following crop-by-crop discussion notes whether there have been bird kills associated with field studies or incident reports linked to the application of carbofuran in a specific crop. Details pertaining to these kills are described later in this chapter. It should be noted, however, that lack of a documented bird kill associated with a particular use site does not suggest that there are no kills associated with the use of carbofuran on the site.

As previously stated, exposure is often comparable among sites, and bird kills associated with one site strongly suggests that kills also will be associated with similar sites. For example, a peanut field at planting time will appear similar to a nearby corn field (i.e., recently tilled bare soil in the conventional tillage practice). Whereas EPA has numerous documented kills associated with carbofuran use in corn, there are no documented kills in peanuts. When EPA lacks documentation of kills for a given site, this does not necessarily reflect a true absence of kills associated with the use of carbofuran at that site. Rather, the lack of documented kills may be due to factors including lack of systematic observations for that site and the lack of an effective system for reporting and verifying bird kills associated with pesticide use. This is discussed further in Section II.F, Bird Kill Incidents from Direct Poisoning.

a. Corn

Corn is grown throughout an extensive geographic area in the United States. Therefore, of the 10 use sites discussed in this document, the greatest variety of species and numbers of birds are found in corn fields. Most of the species in Table II-1 can be seen in or near corn fields. Researchers have documented birds using corn fields throughout the crop cycle for various activities, including feeding, resting, nesting, and brood-rearing. Carbofuran is applied either at-planting or postemergence, and any of these avian activities may occur at these times of application. Endangered species found in corn fields can include the Aleutian Canada goose, Mississippi sandhill crane, whooping crane, Attwater's greater prairie-chicken, piping plover, and the bald eagle. There are both field studies and incident reports documenting bird kills associated with the use of carbofuran in corn.

b. Sorghum

Carbofuran is used as an at-planting insecticide and nematocide treatment at times when bird species may be using sorghum fields for activities including feeding and nesting. In Arkansas, birds such as waterfowl, doves, turkeys, and blackbirds may be using sorghum fields for feeding. In other states such as Kansas, Missouri, Kentucky, and New Mexico, birds may be expected to use sorghum fields for feeding, nesting, and brood-rearing. These birds may include quail, waterfowl, songbirds, pheasants, doves. In Texas, the Attwater's greater prairie-chicken, Aplomado falcon, and the whooping crane, all endangered species, may frequent sorghum fields. In one documented incident, whooping cranes had to be chased from a sorghum field treated with granular carbofuran (U.S. Fish and Wildlife Service 1986a).

c. Soybeans

Carbofuran is applied as an at-planting treatment for Mexican bean beetle and nematode control in soybeans. Birds such as quail use soybean fields for feeding, brood-rearing, and resting. Mourning doves, wild turkeys, and a variety of ducks and geese will use fields for feeding. In Iowa and Illinois, ring-necked pheasants are known to nest, rear broods, and rest in soybean fields. In Iowa, other upland species such as the Hungarian partridge will use soybean fields for feeding and brood-rearing. In Kentucky, songbirds are known to feed, nest, and rear broods in soybean fields. In Michigan, ring-necked pheasants feed and rear broods. In Maryland and Virginia, ring-necked pheasants and northern bobwhites feed and nest in soybean fields. Endangered species that may use soybean fields include the bald eagle, whooping crane, and the Mississippi sandhill

crane. There are incident reports documenting bird kills associated with the use of carbofuran in soybeans.

d. Rice

Carbofuran is applied to rice as an insecticidal preplant, preflood, or postflood treatment. A diversity of water bird species including rails, herons, purple gallinule, and common snipe may use rice fields. Waterfowl such as mallards, mottled ducks, blue-winged teal, and Canada geese may use the rice fields for nesting. Blackbirds, bobolinks, and grackles may also frequent fields. These birds are exposed to carbofuran by feeding on invertebrates, seed, the crop itself, wild plants, and other animals associated with rice crops. Hawk species are known to search rice fields for prey. There are numerous incident reports, including secondary poisonings, documenting bird kills associated with the use of carbofuran in rice.

e. Peanuts

Insecticidal and nematicidal treatment of peanuts may be made at planting or pegging time, the timing dependent upon the target pest. (Pegging refers to the early pod and seed developmental stage of the peanut plant.) Birds associated with peanut fields include quail, wild turkeys, songbirds, waterfowl, and mourning doves. In Texas, the Attwater's greater prairie-chicken may also be found. At the times of application, bird activities primarily entail feeding, seeking cover, and resting.

f. Tobacco

Carbofuran insecticidal nematicidal application of carbofuran to tobacco occurs prior to transplanting the young plants. In Kentucky, doves may use fields for feeding, quail use fields for hunting insects, brood-rearing, and resting, and songbirds use fields for hunting insects and for cover. Other states report songbirds feeding in or near tobacco fields, and wild turkey and northern bobwhite using tobacco fields for feeding, nesting, brood-rearing, and resting.

g. Cotton

Carbofuran is applied as an at-planting insecticide application to cotton. Although only minor cotton acreage (primarily in Texas) is treated with carbofuran, certain upland bird species such as quail may be nesting and brood-rearing at this time in central and western Texas. Also, sandhill cranes and the Aplomado falcons may be exposed while foraging cotton fields in this state. Smaller species such as laughing gulls and swallows also feed in cotton. These birds are attracted to dead

and dying insects resulting from pesticide applications (White et al. 1979 and 1983).

h. Cranberries

Carbofuran is applied as an insecticide to non-flooded cranberry bogs in Washington and Oregon. During the public comment period following the PD 1, Washington State University provided some observations regarding the presence of birds in cranberry bogs (Comment #2 listed in Appendix 12). Birds were observed in cranberry bogs and on the vegetated edges of the bogs. Birds observed in the bogs included robins, sparrows, blackbirds, and starlings. Birds observed in areas near the bogs included blue jays, juncos, thrush, flycatchers, chickadees, band-tailed pigeons, and a variety of warblers.

i. Pineseed Orchards

Insecticidal applications of carbofuran in pine seed orchards in the southeastern United States are broadcast in winter or early spring, thereby exposing several species of overwintering passerine birds. In a field study (Overgaard et al. 1983) discussed in Section C of this chapter, researchers listed the different bird species that were observed foraging before carbofuran application to pine seed orchards in Mississippi, Florida, South Carolina, and Louisiana. Pine warblers were common to all sites. Other birds observed include American robins, several species of woodpeckers, Carolina chickadees, eastern bluebirds, Carolina wrens, red-winged blackbirds and ruby-crowned kinglets. Birds of prey are expected to hunt in these orchards and could include the loggerhead shrike, and red-shouldered, red-tailed, and sharp-shinned hawks. There are field studies and incident reports documenting bird kills associated with the use of carbofuran in pine seed orchards.

j. Sunflowers

Carbofuran is applied to sunflowers as an at-planting insecticide treatment. The sunflower-growing region is mainly in the prairies, which comprises about 10% of the total waterfowl breeding areas of North America and produce 50% of the annual duck population. A variety of bird species are likely to be present during carbofuran application, including upland game birds, songbirds, waterfowl, shorebirds, and marshbirds. These birds would be expected to frequent sunflower fields and border areas for feeding, nesting, cover, brood-rearing, and bedding. These species could include gadwalls, blue-winged teals, mallards, northern pintails, and American wigeons.

2. Sources of Exposure

Having established that birds will likely be present when carbofuran is applied, EPA evaluated how birds could be exposed.

a. Granules

Birds may ingest carbofuran granules as they forage for seeds or grit on or below the surface of the soil. Granules are approximately the same size as grit. Grit is small, irregularly shaped particles, normally range in size from a grain of sand to a small stone. Grit is an aid in the digestion of food by helping to grind food in the gizzard. Balcomb (1980) reports that "there is nearly complete size overlap between granular pesticides and grit known to be palatable to birds."

Birds may be exposed to carbofuran granules because application results in granules on the surface of the soil and below it. Granules may be applied using ground equipment at the beginning of the growing season when corn or other crops are planted. Granules on the soil surface may result from actually being applied to the soil surface using band application or from incomplete incorporation following in-furrow application. When carbofuran is applied using in-furrow application, granules are dropped into the furrow along with the seeds and then covered with soil. Incomplete incorporation of granules generally results. Granules also become exposed on the soil surface when (1) machinery is being loaded, (2) planter shoes are lifted out of furrows to permit turning, and (3) planter shoes rise out of the soils of irregularly contoured fields.

Band application is the most common method of application and is a highly variable agricultural practice. The manner of banding varies with the planter models used and the specific configuration selected by the farmer. Optional settings of opening and closing discs, planter shoes, drop tubes, granule spreaders, and press wheels all result in variation. Recommendations to apply granules in front of the press wheel are made usually to ensure greater granule incorporation because the granules will be pressed into the soil after application. However, the equipment is not always configured in this manner. Some planter models such as the John Deere Max-Emerge¹ may not necessarily use the traditional press wheel.

Birds are expected to ingest these granules and may be seen feeding in fields during spring planting operations, often following behind planting equipment. Being opportunistic, some birds are probably attracted to soil invertebrates, seeds, or old crop remains, which may be brought to the tilled surface by the

¹registered trademark

planter. Birds foraging for seeds or grit may be unable to avoid ingesting granular pesticides in this manner.

Spring planting operations using granular pesticide applications may also attract migratory species of birds to fields. Many species of migratory birds will be on their northerly migrations at this time and may land in fields to feed. In many cases, they will be ending an extensive migration period.

Granules may also be applied aerially later in the season. These granules are not incorporated. Birds are exposed to granules falling on the field surfaces and into the whorls of the corn plants. Many insect-foraging birds will actually use the mature crop because they are attracted to it by the presence of pest insects. Moreover, aerial application of granules can contaminate more of the field edge than applications at the beginning of the season because of the inaccuracy of the aerial placement of granules. This increases the likelihood of exposure to birds using the edge habitat. As ecological "edges" are often areas of high bird activity, contamination of edges may increase both the numbers and species of birds that will be exposed to the granules.

Although label directions were followed, several researchers have confirmed that band and in-furrow application of carbofuran or other granular pesticides applied using conventional commercial application equipment results in exposed granules on the soil surface. Using a variety of incorporation techniques and several models of planters operated at different speeds, Hummel (1983) demonstrated that granule incorporation ranged from 69.0% to 96.3% for band and generally 99% for in-furrow application. Beskid and Fink (1981) and Dingleline (1985) demonstrated substantial soil surface exposure of granular corn rootworm pesticides after incorporation by commercial farm equipment. Whitehead (1975) reported that carbofuran granules were present on the surface of the soil after application to corn.

In field studies discussed in Section C of this chapter, researchers reported granules remaining on the soil surface after the granules were incorporated during application. Balcomb et al. (1984a) reported that "Furadan 10G granules were exposed on the surface throughout the length of virtually every furrow Large spills in turn areas, however, remained visible throughout the 21-day study." This study also indicated that after 3 weeks, granules from one spill site retained 89% of the original carbofuran content.

In another field study, Balcomb (1983) reported "carbofuran granules were readily apparent on the soil surface in treated corn fields. This is considered typical of both in-furrow and

band applications to corn . . ." (and was exclusive of row-end spillage).

Erbach and Tollefson (1983) confirmed that commonly used agricultural practices are not sufficient to achieve complete incorporation of carbofuran granules into the soil and also showed that carbofuran granules applied as a band application using conventional commercial agricultural equipment resulted in granules remaining unincorporated. Carbofuran was placed either in front of the planter press wheel, which then covered and pressed down the granules, or behind the press wheel. The granules were also incorporated using a drag chain or spring tine. The following table summarizes the percent of granules that remained unincorporated, depending on whether the granules were applied in front of or behind the planter press wheel:

Incorporation Method	Exposed granules (%)		
	In Front	Behind	Average
Drag chain	7.9	16.0	12.0
Spring tine	5.8	7.4	6.6
Press wheel only	14.7	40.2	27.4
Average	9.5	21.2	15.3

These percentages of granules probably underestimate the actual number of granules remaining because granule counts were within rows and did not include row ends. Also, the fluorescent techniques used to visualize the granules were not 100% efficient and thus did not allow the researchers to identify all of the granules in the study (Tollefson 1979).

Based on the limited available data, EPA calculated estimates of the number of granules that would remain exposed on the soil surface as a result of incomplete incorporation (U.S. Environmental Protection Agency 1987e). Data presented by Erbach and Tollefson (1983) suggest that a large percentage of granules will remain on the soil surface after incorporation. However, EPA used conservative estimates of 15% and 1% for banded and in-furrow incorporation methods, respectively, and a 40 inch row spacing. Therefore, the numbers presented below probably underestimate the magnitude of exposed granules.

Formulation	Application Rate (lb ai/A)	Application Method	Granules exposed/sq ft
15G	3	7-inch band	596
	3	In-furrow	93
	1	7-inch band	198
	1	In-furrow	31
10G	3	7-inch band	837
	3	In-furrow	130
	1	7-inch band	279
	1	In-furrow	43

At a minimum, birds may potentially be exposed to the number of granules/sq ft that are on the soil surface. It is likely that birds that probe the soil for insects and other items also may be exposed to granules below the soil surface. The number of exposed granules/sq ft for other application scenarios (i.e., other application methods and rates) is described in later sections of this document. These numbers are significant because acute toxicity studies indicate that a single granule of carbofuran can kill a small bird.

b. Invertebrates

Dietary exposure of birds to granular carbofuran may also occur via feeding on invertebrates such as earthworms (Lumbricus terrestris). In one of the field studies, Balcomb et al. (1984a) reported whole-body residues ranging from 0.3 to 670 ppm in 11 of 12 samples of earthworms analyzed. These worms were found in the furrows after carbofuran application to corn. Worms were washed prior to chemical analysis to remove adhering carbofuran granules. As a result, whole-body residues did not include the additional carbofuran contained in the granules attached to the body. If present, these granules would provide greater residues to any organism ingesting such worms. American robins and other birds were killed in these fields. Section D.2 of this chapter provides additional discussion of these field studies.

c. Vertebrates

Dietary exposure for predatory birds such as hawks and eagles may occur from ingestion of vertebrates such as mice and small birds that have ingested carbofuran granules. Carbofuran residues have been found in mice and birds and are discussed in Section C of this chapter.

3. Residues in Birds

There are considerable data documenting that birds have died as a result of exposure to carbofuran. There have been both direct poisoning from granules and secondary poisonings from ingestion of vertebrates and invertebrates that have been contaminated with carbofuran.

Many birds that have been killed were analyzed for carbofuran residues. For example, the California Department of Fish and Game has reported several bird kill incidents from 5G used on rice to control the rice water weevil (California Fish and Game 1984a and 1984b, 1985, 1986a, 1986b, 1986c, 1987a, and 1987b). Necropsies and chemical analyses established the cause of death as granular carbofuran poisoning. Table II-2 summarizes some of the residue information for some of these kill incidents in which both direct and secondary poisonings resulted. Direct

Table II-2. Carbofuran residues in wildlife from 5G use in California rice fields.

<u>Occurrence</u>	<u>Sample</u>	<u>Carbofuran Residue (ppm)</u>
April 1984	Duck gizzard	2.3
	Duck gizzard	68
	Duck gizzard	37
	Duck gizzard	<3
April 1984	Mallard gizzard	3.7
	Mallard gizzard	11
	Mallard gizzard	28
April 1984	Gadwall gizzard (five birds)	1.2 - 14
November 1985	Duck gizzard	41
	Northern harrier	64
	crop contents	
	American coot gizzard	310
	Mallard gizzard	37
October 1986	Mallard gizzard	23
	Waterfowl gizzard	0.8
	Waterfowl gizzard	4.6
	Waterfowl gizzard	24
	Waterfowl gizzard	40
	Waterfowl gizzard	64
	Waterfowl gizzard	270
	Waterfowl gizzard	649
	Waterfowl gizzard	59
	Waterfowl gizzard	0.4
	Waterfowl gizzard	0.3
	Waterfowl gizzard	90
	Waterfowl gizzard	190

poisoning incidents resulted in carbofuran residues in waterfowl carcasses ranging from 0.3 to 640 ppm. Secondary poisoning occurred to a Northern harrier, which was reported to be poisoned almost to the point of death and was sacrificed in the rice field. Crop contents were examined and included duck viscera, dead flies, live maggots, and 64 ppm carbofuran. The brain acetylcholinesterase level was depressed approximately 84%, which is generally considered indicative of lethal exposure to a strong anticholinesterase agent (Ludke et al. 1975, Hill and Mendenhall 1980, Hill and Fleming 1982).

Further discussion of the results of carbofuran exposure and residues in wildlife are in Sections C, D, and E of this Chapter. These sections discuss the field studies, bird kills from direct poisonings, and secondary poisonings, respectively.

C. Direct consumption of granules by birds

1. Introduction

Field data suggest that the greatest risk of granular products to avian wildlife may result from birds exposed to granules and ingesting them directly. A method of assessing avian risk from direct granular ingestion is by comparing avian acute toxicity data (number of granules equal to an LD50 dose) to exposure (number of granules exposed per unit area).

2. Toxicological Hazard

Carbamate pesticides like carbofuran are acutely toxic to birds and are relatively quick acting. Granular formulations of these pesticides expose birds via ingestion to discrete doses of the pesticide. The manner of exposure (ingestion of granules) is comparable to that in LD50 toxicity testing. For these reasons, the LD50 value (milligrams of pesticide per kilogram of bird body weight which will kill 50% of the test population) is an appropriate toxicity parameter to assess avian hazard. For a granular pesticide where an avian laboratory LD50 value and the average or median weight of a granule is known, the number of granules that will kill 50% of the population can be directly calculated. It is described as number of granules per bird LD50 (# granules/LD50). The following values for carbofuran are based upon the lowest (most toxic) LD50 value available for each representative group (see Smith 1987, Schafer and Brunton 1979).

Bird group	Weight ² (g)	LD50 (mg/kg)	LD50/ bird	Active Ingredient (mg)/10G granule	Granules/ LD50
Waterfowl	1000	0.24	0.24	0.032	7
Upland gamebird	180	1.30	0.23	0.032	7
Songbird	50	0.42	0.02	0.032	0.6

In this analysis EPA considered behavioral factors, most notably the number of granules that a bird is likely to pick up. Data from field studies indicate that a bird will pick up and ingest up to 53 granules of carbofuran. This value of 53 is considerably greater than the number of granules equalling an LD50 dose (i.e., 0.6 for songbirds and 7 for waterfowl and upland gamebirds. Therefore, it is highly likely that a bird can readily pick up and ingest enough granules of carbofuran to equal a toxic dose. This assumption is corroborated by the documentation describing bird kills, from both field studies and field incidents, resulting from actual use of granular carbofuran.

EPA calculated similar values for other the other granular formulations of carbofuran. However, the actual weight of the granule (0.32 mg) was available only for the 10G. For the other formulations of carbofuran EPA used an estimate of 0.30 mg. This is the median of the values for granule weights reported by Balcomb et al. (1984b) and Hill and Camardese (1984).

3. Exposure

In assessing the risk to birds associated with the use of a pesticide, it is useful to examine the acute toxicity in the context of the potential exposure, with the exposure being measured on an area (e.g., square foot) basis. DeWitt (1966) analyzed available avian laboratory and field studies and reported that there is a possible relationship between the lethal quantity of pesticide ingested by birds (mg pesticide/bird), and the quantity of pesticide deposited per unit area during pesticide applications. He concluded that "losses of birds may be expected if the quantity of toxicant per square foot equals or exceeds the quantity causing death of quail in short-term feeding tests". The "short-term" feeding tests provide data including LC50 toxicity values. However, the LD50 value is a more appropriate parameter to assess avian hazards for granular formulations of highly toxic pesticides like carbofuran than the LC50 value.

² Values for weight are based on average values for representative birds for each group (Dunning 1985). These representative birds are mallard, northern bobwhite, and red-winged blackbird for waterfowl, upland gamebird, and songbird, respectively.

In 1977, Felthousen of OPP's Ecological Effects Branch (EEB) proposed the square foot as the unit area of exposure for determining risk to birds from exposure to granular pesticides (Felthousen, 1977). For comparative purposes, any consistent dimension for unit area could be used. However, the square foot is a useful dimension for reasons including (1) it is easier for a person to visualize the number of granules in a square foot than for a larger dimension such as an acre or hectare and (2) most birds, even a small songbird, should be able to readily forage over a square foot of ground.

It is infeasible to precisely determine the number of granules exposed per unit area for all application scenarios. Even under ideal application conditions, there is considerable variability in application accuracy and efficiency of incorporation and coverage of granules (O'Brien 1987). However, based upon the limited number of studies reported in the literature (Erbach and Tollefson 1983, Hummel 1983, Beskid and Fink 1981, Dingledine 1985, Balcomb et al. 1984), one can derive standardized estimates of the number of granules per square foot.

Band and in-furrow applications typically include some type of incorporation (Erbach and Tollefson 1983, Hummel 1983). Based on these reports, band applications can result in 6% to 40% of the applied granules being exposed on the surface of the soil with an average value of 15% (Erbach and Tollefson 1983). The reports indicate that only 1% of the applied granules are exposed on the soil surface following in-furrow applications. The researchers qualified that their estimates are conservative because of technical limitations in their technique for detecting granules exposed on the soil surface. In addition, unlike the conditions of normal pesticide applications, their applications were highly controlled with respect to factors including machine calibration. Therefore, the values for exposure that EPA uses in its analysis, 15% and 1% for band and in-furrow applications, respectively, are likely conservative estimates of exposure under actual field conditions.

When applying pesticides, the application equipment is typically raised from the soil in turn areas at row ends (turn rows). This will generally result in the poor to no incorporation of granules that are deposited in these areas. Under this circumstance, turn rows would have considerably more granules/sq ft exposed than in areas where granules are incorporated. For this analysis, EPA estimated the number of granules exposed in turn row areas using the assumption of no incorporation. Although the directions on the label may require incorporation, in actual use the pesticide applicator cannot practically do this immediately after the granules are deposited. In the case of turn rows, it is likely that an applicator would complete the pesticide application on the field before returning to the turn rows to incorporate the granules that are on the

surface. This has particularly significant implications in for granular carbofuran which can kill birds within minutes and which is so toxic that a single granule can kill a small bird.

The number of carbofuran granules per square foot was estimated based upon current label information and the equations below. See Table II-3 for estimates of the number of granules per square foot for carbofuran at minimum and maximum application rates for the 10 use sites examined in this document.

Broadcast application and turn rows:

$$\frac{\# \text{ lb a.i.}}{\text{Acre}} \times \frac{454\text{g}}{1 \text{ lb}} \times \frac{1000\text{mg}}{\text{g}} \times \frac{\text{granule}}{\text{mg a.i.}} \times \frac{\text{Acre}}{43560 \text{ sq ft}} = \frac{\text{granules}}{\text{sq ft}}$$

Band application (Assume 15% exposed granules):

$$\frac{\# \text{ lb a.i.}}{\text{Acre}} \times \frac{454\text{g}}{1 \text{ lb}} \times \frac{1000\text{mg}}{\text{g}} \times \frac{\text{granule}}{\text{mg a.i.}} \times \frac{\text{Acre}}{\# \text{ linear ft of row}} \times \frac{1}{\# \text{ ft of band width}} \times 0.15$$

$$= \frac{\text{granules}}{\text{sq ft}}$$

In-furrow applications (Assume 1% exposed granules):

$$\frac{\# \text{ lb a.i.}}{\text{Acre}} \times \frac{454\text{g}}{1 \text{ lb}} \times \frac{1000\text{mg}}{\text{g}} \times \frac{\text{granule}}{\text{mg a.i.}} \times \frac{\text{Acre}}{\# \text{ linear ft of row}} \times \frac{1}{\# \text{ ft of band width}} \times 0.15$$

$$= \frac{\text{granules}}{\text{sq ft}}$$

4. Risk Assessment

Several types of information can be used to assess the risk that granular carbofuran poses to birds. These include data from studies showing that carbofuran is highly acutely toxic, 1 granule can provide a sufficient dose to kill some small birds, that application of carbofuran can potentially result in significant numbers of granules being exposed on the soil surface, and that birds are likely to encounter and ingest the granules (See Section II.D, Field studies). In addition, the following equation can be used to relate the toxicity to exposure.

$$\text{RISK} = \frac{\text{EXPOSURE}}{\text{TOXICITY}} = \frac{\text{GRANULES/SQ FT}}{\text{GRANULES/LD50}} = \frac{\text{LD50s}}{\text{SQ FT}}$$

EPA estimated the number of avian LD50s/sq ft for each of the 10 carbofuran use sites discussed in this document. EPA calculated the minimum and maximum LD50/sq ft values for broadcast, band, in-furrow application, and turn row areas. The results are found in Table II-3 and a summary of Table II-3 follows.

Use Site	LD50s/sq ft			
	Songbirds		Upland Gamebirds and Waterfowl	
	Minimum	Maximum	Minimum	Maximum
Corn	68	2211	6	187
Cotton	68	527	6	45
Cranberry	1052	1052	89	89
Peanuts	32	2632	3	223
Pineseeds	5170	10002	438	846
Rice	156	261	13	22
Sorghum	56	1033	5	89
Soybeans	68	2104	6	178
Sunflowers	68	1368	6	116
Tobacco	1368	3159	114	267

These estimates indicate that each of the uses of granular carbofuran poses a potential risk to each of the representative bird groups. The field studies and incident reports, which are summarized in the following sections, corroborate the finding that use of granular carbofuran poses significant risk to birds. Evaluation of the field studies indicate that avian mortality occurred at estimated risk levels as low as 6 LD50s/sq ft.

D. Field Studies

Documented field kills of birds due to the use of granular carbofuran are important data confirming the avian risk as estimated in the previous assessment section. Field incident reports and field studies provide confirmation of this risk.

EPA received and evaluated 6 field studies. The results are summarized in Table II-4. These studies investigated the loss of bird resulting from soil-incorporated uses of 10G and 15G applied by band and in-furrow methods according to the label directions and 10G applied with specialized equipment.

The conditions surrounding these field studies and the hypotheses being tested varied, causing a lack of standardization among the studies. For example, one study investigated the effect of using specialized application equipment in pine seed orchards on avian mortality, and another investigated whether or not pesticide-induced mortality in corn was accompanied by detectable residues in bird tissue. As a result of the variation, one must consider a factors including habitat and behavior of the species exposed, in addition to counting bird mortalities (body count) when interpreting these studies. Mortalities alone, without considering other factors, do not indicate the impact of pesticide application.

Table II-3 Number of LD50s/sq ft for waterfowl (W), upland gamebirds (G), and songbirds (S) based on use of granular carbofuran (Application method key: BA = banded, BR = broadcast, IF = in-furrow, TR = turn row).

Crop	Method	Rate	Width(inches)		#ai	Granules/ sq ft	LD50s/sq ft		
		(#ai/A)	Row	Band			W	G	S
CORN	BA	1.0	40	7	10	279	38	38	443
CORN	BA	3.0	40	7	10	837	112	114	1329
CORN	BR	1.0			10	326	44	45	518
CORN	IF	1.0	40	3	10	43	6	6	68
CORN	IF	3.0	40	3	10	130	17	18	206
CORN	TR	1.0	40	7	10	326	44	45	518
CORN	TR	4.2	28	7	10	1368	184	187	2171
CORN	BA	1.0	40	7	15	198	37	38	450
CORN	BA	3.0	40	7	15	596	113	115	1355
CORN	BR	1.0			15	232	44	45	527
CORN	IF	1.0	40	3	15	31	6	6	70
CORN	IF	3.0	40	3	15	93	18	18	211
CORN	TR	1.0	40	7	15	232	44	45	527
CORN	TR	4.2	28	7	15	973	184	187	2211
COTTON	IF	1.0	40	3	10	43	6	6	68
COTTON	TR	1.0	40	3	10	326	44	45	518
COTTON	IF	1.0	40	3	15	31	6	6	70
COTTON	TR	1.0	40	3	15	232	44	45	527
CRANBERRY	BR	2.0			15	463	88	89	1052
PEANUTS	BA	2.0	36	12	10	293	39	40	465
PEANUTS	BA	5.0	36	18	10	489	66	67	776
PEANUTS	IF	0.5	36	3	10	20	3	3	32
PEANUTS	IF	1.0	36	3	10	39	5	5	62
PEANUTS	TR	0.5	36	3	10	163	22	22	259
PEANUTS	TR	5.0	36	3	10	1629	219	223	2586
PEANUTS	BA	2.0	36	12	15	208	39	40	473
PEANUTS	BA	5.0	36	18	15	347	66	67	789
PEANUTS	IF	0.5	36	3	15	14	3	3	32
PEANUTS	IF	1.0	36	3	15	28	5	5	64
PEANUTS	TR	0.5	36	3	15	116	22	22	264
PEANUTS	TR	5.0	36	18	15	1158	219	223	2632
PINESEED	BR	10.0			10	3257	438	446	5170
PINESEED	BR	19.0			10	6188	832	846	9822
PINESEED	BR	10.0			15	2316	438	445	5264
PINESEED	BR	19.0			15	4401	832	846	10002
PINESEED	BR	0.1			10	38	5	5	57
PINESEED	BR	0.1			15	25	5	5	57
RICE	BR	0.5			2	869	22	22	261
RICE	BR	0.3			3	347	13	13	156
RICE	BR	0.4			3	463	18	18	209
SORGHUM	BA	1.0	40	7	10	279	38	38	443
SORGHUM	IF	0.8	40	3	10	35	5	5	56
SORGHUM	IF	1.0	40	3	10	43	6	6	68
SORGHUM	TR	0.8	40	3	10	261	35	36	414
SORGHUM	TR	2.0	20	3	10	651	88	89	1033

Table II-3. (continued)

Crop	Method	Rate (#ai/A)	Width(inches)		#ai	Granules/ sq ft	LD50s/sq ft		
			Row	Band			W	G	S
SOYBEANS	BA	1.5	40	7	10	419	56	57	665
SOYBEANS	BA	2.0	40	7	10	558	75	76	886
SOYBEANS	IF	1.0	40	3	10	43	6	6	68
SOYBEANS	IF	1.5	40	3	10	65	9	9	103
SOYBEANS	TR	1.0	40	3	10	326	44	45	518
SOYBEANS	TR	4.0	20	3	10	1303	175	178	2068
SOYBEANS	BA	1.5	40	7	15	298	56	57	677
SOYBEANS	BA	2.0	40	7	15	397	75	76	902
SOYBEANS	IF	1.0	40	3	15	31	6	6	70
SOYBEANS	IF	1.5	40	3	15	46	9	9	105
SOYBEANS	TR	1.5	40	3	15	347	66	67	789
SOYBEANS	TR	4.0	20	3	15	926	175	178	2104
SUNFLOWERS	BA	1.3	30	7	15	194	37	37	441
SUNFLOWERS	BA	2.6	30	7	15	387	73	74	880
SUNFLOWERS	IF	1.3	30	3	15	30	6	6	68
SUNFLOWERS	IF	2.6	30	3	15	60	11	12	136
SUNFLOWERS	TR	1.3	30	3	15	301	57	58	684
SUNFLOWERS	TR	2.6	30	3	15	602	114	116	1368
TOBACCO	BR	3.0			10	977	131	134	1551
TOBACCO	BR	6.0			10	1954	263	267	3102
TOBACCO	BR	3.0			15	695	131	134	1580
TOBACCO	BR	6.0			15	1390	263	267	3159

For example, in one study over 90% of the birds killed were horned larks. This is a flocking species that feeds and nests on the ground in agricultural fields and is highly likely to be exposed to pesticide granules. It is unlikely that flocking will occur every time carbofuran is used, and this must be considered when comparing the field studies. However, when flocking does occur, large numbers of birds can be killed in a localized area. Therefore, flocking must be considered in assessing the overall risk to birds.

For pesticides like carbofuran that can kill relatively quickly, body counts provide confirmation of mortality resulting from actual use. However, in order for this data to provide a realistic estimate of the extent of mortality in the study, the researchers must search an adequate area and know what percent of carcasses are recovered. Rosene and Lay (1963) indicated that finding a few dead animals suggests that considerable mortality has occurred and that failure to find carcasses is poor evidence that no mortality has occurred. If researchers know the reliability of the search, the magnitude of the kill incidents can be estimated.

If adequate areas are not searched, body counts may lead to underestimating the bird mortality that occurred. Balcomb (1986) provides findings of a study wherein more than 60% of small songbird carcasses disappeared from agricultural fields overnight. The loss is attributed to predation and scavenging of dead or dying birds. The number of birds found will be underestimated if carcass searches do not begin soon after application, searches are not frequent enough, the area searched is too small, or enough search personnel are not available.

Also, knowledge of the population present at the time of the study is essential to an understanding of the magnitude of effect. For example, researchers involved with several studies in corn attempted to measure acute mortality after the application of carbofuran granules. As with all at-planting soil-incorporated uses, there was not crop stand at the time these studies were initiated. This condition could greatly influence the numbers of birds utilizing the fields, depending on the species present at a particular locality, their habits, and habitat requirements. Different number of birds might be exposed in different localities or even at different times of the year at the same locality.

The studies for evaluating secondary mortality are even less standardized than those evaluating direct mortality. Problems associated with studying raptor populations in the wild are well documented (Robbins et al. 1986, Bystrak 1981, Fuller and Mosher 1981, FMC Corporation 1986a and b). Most species of raptors are secretive, have large home ranges, occur at relatively low densities, and often inhabit roadless areas. These factors add to the difficulties encountered by wildlife toxicologists studying field effects on raptors.

Table II-4. Summary of the field studies for carbofuran.

Study	Crop	Formu- lation	Applica- tion	Acres Searched	Morta- lities	Mortali- ties/A	Estimated LD50s/ft ² in treated areas ³		
							S	G	W
1	Corn	10G & 15G ¹	Band (4 lb ai/A)	254	877 78 ²	3.6 ¹ 0.3 ²	1172	152	152
2	Corn	10G	In-furrow (1 lb ai/A)	92	10	0.1	68	6	6
3	Corn	10G	In-furrow (1 lb ai/A)	34	23	0.7	68	6	6
4	Pine- seed orchards	10G	Specialized equipment (25 lb ai/A)	30	12	0.4			
	Pine- seed orchards (SC)	10G	Specialized equipment (25 lb ai/A)	30	26	0.9			
	Pine- seed orchards (MS)	10G	Specialized equipment (25 lb ai/A)	30	19	0.6			
	Pine- seed orchards (LS)	10G	Specialized equipment (25 lb ai/A)	27	39	1.4			
5	Corn (IL)	10G & 15G ¹	Band (1 lb ai/A)	171	92	0.5	443	38	38
	Corn (IA)	10G & 15G ¹	Band (1 lb ai/A)	307	32	0.1	443	38	38
6	Corn (TX)	10G & 15G ¹	In-furrow (1 lb ai/A)	214	58	0.3	68	6	6

¹ As the study plots were close together, birds may have moved between plots. The researchers determined that carbofuran poisoning was the cause of death, but they could not determine whether the 10G or 15G was responsible. Because the data for the 10G and 15G plots are not independent, the mortality rates are assumed to be the same.

² Most (91.2%) of the birds killed in the study were a flock of horned larks. This rate is calculated without the horned larks.

³ S = songbirds, G = upland gamebirds, and W = waterfowl.

For Pine-seed orchards the use of the specialized equipment precluded the estimation of LD 50s/ft².

1. Field Study 1

This field study investigated the effect of granular carbofuran on avian populations associated with corn fields (FMC Corporation 1983). Study sites were located in Elberta, Utah. 10G and 15G were applied at-planting according to label directions as a 7-inch band and incorporated into the soil over the seed furrows. 10G was applied using 4 lb ai/A to 112 acres, and 15G using 4 lb ai/A to 142 acres. A control plot of 104 acres with no carbofuran treatment was also included. The fields were adjacent to one another.

Field searches were conducted over 60 days. Avian acute poisoning occurred, and fatalities were observed throughout the 60-day monitoring period. The duration of the monitoring period may have influenced the body count because more search time was available to encounter birds killed later in the study.

Researchers reported 373 dead birds in the 10G fields, 504 birds in the 15G fields, and 34 birds in the control (Table II-5). Because the fields were so close together, it is likely that some birds moved among the fields. Necropsy results indicated that carbofuran was the cause of death but did not indicate whether 10G or 15G was responsible. Consequently, the data from the two treatments are not independent. Carcass analysis of dead birds in the control fields indicated that they died from carbofuran. As a result, EPA concludes that they were poisoned from exposure to carbofuran on the treated plots. A total of 911 dead birds were found in the fields or field margins.

Fourteen species of birds and one unidentified duck were involved. Of the 911 birds killed, 831 were horned larks. Table II-5 provides a summary of the species involved.

Birds were also observed showing symptoms of acetylcholinesterase depression. These symptoms included inability to fly and uncoordinated motion while sitting, standing, or walking.

Necropsies were performed on 145 out of 760 intact carcasses. No evidence of internal or external trauma were found that would implicate another cause of death. However, carbofuran granules were present in the gastrointestinal tract of the majority of the dead birds examined (Table II-6). The gastrointestinal tracts of the 145 dead birds were also analyzed for carbofuran residues (Appendix 2). The number of granules observed in the birds ranged from 0 to 53, while the residues ranged from 0 to 853.2 ppm. Thirty-one birds contained no observed carbofuran granules but still contained lethal levels of carbofuran residues. The residue levels found in the birds were moderately correlated ($r^2 = 0.61$) with the number of granules present.

Table II-5. Summary of dead birds by species and treatment in field study 1

Species	Control	10G	15G	Total
Horned lark	32	355	444	831
Yellow-headed blackbird	1	1	19	21
Brown-headed cowbird	0	0	19	19
Mourning dove	1	6	12	19
Savannah sparrow	0	5	3	8
Ring-necked pheasants	0	2	0	2
Lark sparrow	0	2	0	2
Killdeer	0	0	1	1
Eastern kingbird	1	0	0	1
Common raven	0	1	1	2*
Northern harrier (marsh hawk)	0	1	0	1
Short-eared owl	0	0	1	1
Mallard	0	0	1	1
Gadwall	0	0	1	1
Unknown duck	0	0	2	2
Subtotal (Nonhorned lark)	3	18	60	81
Subtotal (Horned lark)	32	355	444	831
Total	35	373	504	912

* One raven was found during the wildlife utilization portion of the study. This raven was excluded from the final analysis.

There were 15 birds that contained over 10 granules and 4 birds contained over 30 granules. The majority of birds contained between 1 and 10 granules. Even though many dead birds contained granules, most often no granules were found (Table II-5). Many of the birds containing no granules still had lethal carbofuran residue levels detected in their gastrointestinal tracts.

Predators and scavengers appeared to be attracted to the site by the mortality among small birds. Scavenging and predation led to secondary poisoning and the death of a northern harrier (marsh hawk) and two common ravens. Analysis of the stomach contents indicated that these fatalities resulted from the consumption of smaller birds that had been poisoned by carbofuran. The raven contained up to 8.1 ppm carbofuran and up to 38 granules; the northern harrier contained 21.8 ppm carbofuran and 23 granules. A dead short-eared owl was also found. Another northern harrier and raven were also observed exhibiting symptoms associated with acetylcholinesterase poisoning but did not die.

EPA concluded from this study that application of 10G and 15G carbofuran according to label directions results in sufficient exposure to granules that birds are killed either from direct ingestion or secondary poisoning. The study authors (FMC Corporation 1983) concluded that there was no statistically significant difference between the number of birds killed in the 10G and 15G plots. Although EPA determined that the plot data might not be independent, this conclusion is probably correct because the active ingredient is so toxic that either a 10G and 15G granule is toxic enough to kill a wide variety of small birds.

2. Field Studies 2 and 3

These field studies investigated the effect of the application of 10G on birds and other animals. The purpose of the studies was to determine if pesticide-induced mortality is accompanied by detectable residues in bird tissue samples.

Carbofuran 10G was applied at-planting according to label directions using in-furrow application and incorporated into the soil. The application rate was 1 lb ai/A. In Study 2 (Balcomb et al. 1984a, Balcomb unpublished, Jung 1980) and in Study 3 (Balcomb 1983, Balcomb unpublished, Wright 1981) 486 and 200 acres of corn were treated, respectively. A control plot was not included in either study. In both studies granules were reported remaining on the soil surface after carbofuran application.

Table II-6. Number of birds containing granules in field study 1

<u>Number of Birds</u>	<u>Number of Granules</u>
31	0
26	1
26	2
10	3
9	4
7	5
5	6
5	8
4	7
4	9
3	23
2	10
2	16
2	32
1	11
1	14
1	19
1	20
1	24
1	30
1	38
1	53

Field searches were conducted in both studies. In Study 2, approximately 20% of the fields (Balcomb unpublished) and in Study 3 approximately 10% of the fields were searched. Searches were limited because of personnel shortages and generally no more than two individuals were available. In Study 2, fields were searched 24 and 96 hours after carbofuran application. It is not known when the field searches took place in Study 3.

In Study 2, five intact passerine carcasses were found. In addition, the fresh partial remains of four American robins and a common grackle were discovered. This suggests they were partially consumed by scavengers after dying or becoming sick from carbofuran poisoning. Two additional birds were found exhibiting irregular behavior consistent with carbofuran poisoning. A dead white-footed mouse (Peromyscus leucopus) was also found.

Six birds and the white-footed mouse were analyzed (Table II-7). The results indicated residues in the birds ranging from 1.6 to 17.0 ppm. The mouse contained 15.1 micrograms (ug) carbofuran in the gastrointestinal tract/liver sample.

Earthworms were also observed to be dead and dying. They were mainly concentrated in the furrows and contained up to 670 ppm carbofuran, as discussed in Section B.2.b of this chapter. Several of these earthworms had six or more granules stuck to the outside of their bodies (Bowen 1986).

Table II-7. Carbofuran residues in the digestive tract of birds and a mouse exposed to carbofuran in field studies 2 and 3.

Species	Weight (g)	Total carbofuran extracted (ug)	Carbofuran residues (ppm)	Extracted carbofuran as % of LD50 range ¹	
				Low	High
<u>Study 2</u>					
Blue jay	88.0	--	ND ²	--	--
American robin	73.5	16.5	1.6	94	4
American robin	69.6	15.0	1.6	90	4
Red-winged blackbird	41.8	15.0	2.4	86 ³	--
Grasshopper sparrow	15.8	6.5	2.4	171	78
Savannah sparrow	18.5	32.3	17.0	727	31
White-footed mouse	Not reported	15.1	Not reported	--	--
<u>Study 3</u>					
American robin	72.9	172.9	--	994	43
American robin	82.0	166.9	--	847	36
American robin	78.4	139.8	--	743	32
American robin	86.7	159.0	--	764	33
Savannah sparrow	19.1	32.2	--	702	30
White-footed mouse	15.5	35.3 ⁴	--	114 ⁵	--

¹ Acute toxicity data (LD50) are not available for each of the species listed on this table. Therefore, the low and high values for extracted carbofuran as a percent of the LD50 is based on the range of values available. The values used here are 0.24 mg/kg based on the fulvous whistling-duck (Tucker and Crabtree 1970) and 5.62 mg/kg for the European starling (Schafer and Brunton 1979).

² ND = No residues detected at the stated limit of detection (i.e., 0.1 ppm).

³ Based on Red-winged blackbird LD50 of 0.42 mg/kg (Schafer and Brunton 1979)

⁴ Based on stomach contents only.

⁵ LD50 for mouse = 2 mg/kg (National Research Council of Canada 1979)

Based on the average residue levels in the earthworms in this study (Balcomb et al. 1984a), EPA (U.S. Environmental Protection Agency 1987 -) estimated that 3 to 5 average-sized earthworms would be equivalent to 2.6 mg carbofuran. Such a dose would probably be acutely toxic to an American robin. In terms of LD50, this is equivalent to the 33.7 mg/kg, which is much greater than the highest LD50 of 5.62 mg/kg reported for starlings.

In Study 3, 10 intact carcasses, 13 indications of dead birds such as feather spots or partially eaten carcasses, and a dead white-footed mouse were found. Carcass analysis was conducted to determine the amount of carbofuran residues in these dead animals. Birds contained from 32.2 to 172.9 ug of carbofuran. The white-footed mouse contained 35.3 ug of carbofuran in the gastrointestinal tract (tissue and contents). Table II-7 summarizes the results of this analysis.

Two secondary poisonings occurred to one male and one female red-shouldered hawk from feeding on small birds and mammals. The gastrointestinal tract of one of these hawks contained the remains of a shrew and a common grackle. The contents of the gastrointestinal tract contained 47 ug of carbofuran. The tissues of the gastrointestinal tract contained an additional 49.6 ug of carbofuran. The total carbofuran extracted from this hawk was 96.6 ug. Since carbofuran is readily absorbed from the gut and widely transported in the body, the amount of carbofuran extracted from the digestive tract may only be a portion of that ingested by the red-shouldered hawk (Balcomb 1984a).

EPA believes that the observed fatalities in the two studies represent only a portion of those that actually occurred because of the problems described earlier with carcass searches. On the basis of search efficiency alone, Balcomb likely missed 50% of the dead birds. Compounding this, the lack of search personnel limited searches to only a few acres. Balcomb's ability to detect acute mortality was therefore even further reduced, perhaps by another 50%. Thus, Balcomb's carcass totals may conservatively represent only 25% of the birds killed at these sites. EPA did not, however, adjust the mortality rate (Section C.7. of this chapter) to account for these factors.

Although neither study included a control plot, the researchers investigated untreated areas such as hedge rows, roadways, and turf areas at the test site. EPA determined that these untreated areas served as sufficient controls for the following reasons:

- (1) Necropsies of dead birds found in treated fields revealed no internal or external trauma implicating another cause of death. Residue analysis indicated that these birds had lethal levels of carbofuran. Therefore, the bird deaths

- could not be attributed to traumatic causes such as a collision or disease.
- (2) Carbofuran residues extracted from the birds approached or exceeded laboratory LD50 values for sensitive birds such as ducks, red-winged blackbirds, and quelea. As a result, carbofuran is reasonably assured to be the cause of death of these birds.
 - (3) Dead animals were found only in treatment fields. Searches were also conducted in other areas such as hedge rows and turf areas, which can attract higher densities of birds than newly planted fields. However, no birds were found. Therefore, if birds were dying from other causes, carcasses should have been found in these areas as well.

Because Balcomb's studies lacked specific control fields, they may be perceived to be less standardized than studies having controls. However, almost all other carbofuran field studies have shown that birds died on the control plots and contained carbofuran residues and granules. Field Study 1 had over 30 dead "control" birds, which were attributed to granular carbofuran mortality. Thus, EPA determined that none of the studies had independent control plots.

Based on these studies, EPA concludes that carbofuran-induced mortality can be accompanied by detectable residues in the tissues of dead birds.

3. Field Study 4

This field study (Overgaard et al. 1983) investigated the use of carbofuran in pine seed orchards. The purpose of the study was to determine whether improved application equipment (POWR-TILL Seeder) would enhance soil incorporation and reduce avian mortality. The equipment is specialized for use in pine seed orchards. Carbofuran 10G was applied at a rate 25 lb ai/A, which is higher than the average rate of 1 to 2 lb ai/A for corn. Carbofuran was applied to 30 acres in Mississippi, 30 acres in South Carolina, 30 acres in Florida, and 27 acres in Louisiana.

Field searches were made 4 to 5 days after application and resulted in the discovery of 96 bird carcasses. Researchers found 12 birds in the plots in Florida, 26 in South Carolina, 19 in Mississippi, and 39 in Louisiana. Birds exhibiting carbofuran poisoning symptoms were also recorded and included 3 in Florida, 14 in South Carolina, 8 in Mississippi, and 5 in Louisiana. EPA determined that these totals underestimate the number of birds actually killed because of the potential for carcass removal during the first 4 days, a period during which the fields were not searched, and does not account for subsequent avian deaths.

The possible secondary poisoning of two loggerhead shrikes was also noted. One was dead, and the other was dying. Although

loggerhead shrikes are not raptors, they are predatory birds that can feed on small birds, mammals, and insects.

EPA concludes that application with the specialized equipment did result in a high degree of incorporation of granules. However, some granules remained unincorporated on the soil surface, and birds died from carbofuran exposure. Because of the unusual nature of these applications, the study could not be quantitatively used to estimate the bird mortality for at-planting uses on grain crops (Section C.7 of this chapter).

4. Field Study 5

FMC Corporation (1986b) conducted a study on the effects of granular carbofuran on acute mortality and secondary poisoning when applied at-planting to corn in Iowa and Illinois. Carbofuran 10G and 15G were applied at 1 lb ai/A using band application. The actual rate varied slightly at each site, depending on the row spacing of corn. Treatment fields consisted of 171 acres in Illinois and 307 acres in Iowa. Each location had three farms, which contained two plots treated with 10G and 15G, respectively, and a control. The data taken from each farm are not independent because the fields were located close together. Fields were searched at both pre- and postplanting on a regular basis. Generally, two searches per week occurred, continuing for several weeks after planting.

Carcass search efficiency was measured and was about 50% in Illinois and about 65% in Iowa. Predators and scavengers removed carcasses faster in Illinois than in Iowa. Carcasses lasted less than 4 days in Illinois and about 7 days in Iowa. No raptor mortalities or other effects on raptor populations were attributed to granular carbofuran, although a great horned owl, a barred owl, and three eastern screech owl carcasses were found in association with these studies.

The methods employed for complying with the label directions to cover or incorporate the granules after banding do not appear to represent typical agricultural practices employed by farmers planting corn. For example, soil was kicked over exposed granules in some locations. This may not be a common practice among farmers planting hundreds or thousands of acres of grain. Also, the manufacturer's representatives in the field instructed the farmer on how to plant the corn and apply the pesticide. EPA could not quantify the combined effect of the unusual procedures and the influence of the manufacturer's representatives on the results of this field study.

These field studies resulted in finding 92 carcasses and feather spots in Illinois and 32 in Iowa. Birds exhibiting carbofuran poisoning were also noted. FMC found that bird abundance was consistently higher at the field edges than in the

field center. Wildlife utilization of the test areas was higher in Illinois than in Iowa, possibly because the amount of "edge" at the Illinois test sites was greater.

In Iowa and Illinois, 94% of the mortalities occurred within the first 4 weeks after planting. Five small mammal carcasses (eastern mole (Scalopus aquaticus) and white-footed mouse) and an unidentified large mammal carcass were found in Illinois. The animals did not contain carbofuran granules, but one white-footed mouse contained carbofuran at levels of 1.4 ug/g. The researchers could not measure detectable residues of 1 ug/g in the other mammal carcasses. In Iowa, four deer mice (Peromyscus maniculatus) carcasses were found. The carcasses did not contain granules or detectable carbofuran residues of 1 ug/g.

The mortality rate reported for these sites is likely lower than would be expected under typical field conditions. In Iowa, for example, researchers indicated that excessive rainfall may have reduced the toxicity of the granules and accelerated dissipation of the active ingredient from the fields. This would likely decrease the potential for birds to be exposed to the carbofuran, thereby contributing to a lower mortality rate than would have occurred under normal weather conditions. Moreover, the magnitude of underreporting of the mortality rate in this study is not known because the authors did not adequately document their carcass search efficiency, or the rates of carcass removal by predators and scavengers.

Carbofuran residues and granules of carbofuran were found in many of the small bird carcasses collected in this study. Residues ranged from 1.4 to 35 ug/g and numbers of granules from 0 to 11. Approximately 25% of the freshest carcasses were collected for analysis. The researchers could not measure detectable residues of 1 ug/g in other bird carcasses found there. Soil residues were reported to have declined with a half-life of about 20 to 24 days in both Iowa and Illinois.

The study did not provide an adequate discussion of the residue analysis for the bird and mammal carcasses found, including the several dead owls found in the Corn Belt. No explanation of the limit of detection of carbofuran was provided, which appeared to be 10 to 20 times less sensitive when compared to other studies which had lower detection limits. No apparent attempt to check for metabolites of carbofuran in the carcasses containing no detectable parent residue was made.

The secondary poisoning data were not useful because raptors had little or no exposure to carbofuran-contaminated carcasses. The researchers acknowledged that the test plots were chosen without regard for raptor territories. As a result, too few acres were treated, and the home ranges of the raptors were generally outside of the treatment areas. Very little overlap

between the home ranges of radio-tagged raptor and treated areas existed, and the exposure of raptors was not sufficient to draw any conclusions regarding the potential for secondary mortality. In addition, most of the subjects were fitted with transmitters too late in the study. Their potential exposure to most poisoned carcasses could not be adequately tracked, and many of the carcasses could have disappeared from fields or become too decomposed to be attractive by the time the raptors were radio tagged.

In the small number of cases where the opportunity for secondary exposure may have existed, the raptors involved were species such as American kestrels. These birds would be least likely to consume important quantities of small bird and mammal carcasses, which are the most likely sources of active ingredient for raptors feeding in or near granular carbofuran-treated areas. Kestrels mainly consume arthropods, which might not contain sufficient quantities of residues to kill the raptors, even if the arthropods were obtained from treated fields. No American kestrels have been reported killed by granular carbofuran.

The raptor nesting and breeding success portion of the studies were also inadequate. They were started too late in the breeding cycle. The authors indicated that "for many pairs an observation of recently fledged young was the only record of breeding made." The opportunities for exposure of the raptor pairs under investigation were not established. As a result, EPA did not consider the results of this portion of the study in its hazard assessment.

5. Field Study 6

FMC Corporation also studied the effect of carbofuran application to corn in Texas and Florida (FMC Corporation 1986a). Carbofuran was applied at 1 lb ai/A using in-furrow application. Carcass search efficiency was also measured, and study design was similar to Field Study 5. Treated fields consisted of 214 acres in Texas and 230 acres in Florida.

Similar to Field Study 5, the Texas study design regarding the location and closeness of control and treated plots probably obscured the effects of the different formulations. In Texas, researchers found 58 carcasses and feather spots. The reported incidents of mortality did not take into account the removal of carcasses by predators/scavengers or inefficient carcass searching. Carcass removal by predators was reported as higher in Texas than in Iowa and Illinois.

The study found no effects on raptors that FMC could attribute to carbofuran treatments. However, the raptor portion of the study was similar to the raptor work in Field Study 5 and

had many of the same deficiencies. Radiotelemetry was begun relatively late and the evidence submitted suggests that the radio tagged raptors had very few opportunities to be exposed to contaminated prey. The owl study showed that almost no owls were present within the raptor study areas. Also, half of the raptors tagged were American Kestrels. As indicated previously, this species is one of the least likely hawks to be at risk of secondary mortality from granular carbofuran.

One Harris' hawk was found dead during the study, apparently associated with a 15G treatment plot. A supplemental data submission reported this bird was associated with a 10G plot. However, no detectable residue or granules were reported from this specimen. The analytical detection limit was not adequately supported and was 1 ug/g.

Birds were also killed in Florida, but researchers did not attribute any deaths to carbofuran. A large fish crow kill incident (152 birds) occurred at the end of this study. However, this does not fit the typical pattern of mortality usually observed after granular carbofuran treatments. No granules of carbofuran were reported to be observed in these crows.

Bird use of the Florida fields greatly decreased after planting, possibly because of the pesticide treatment program used by the growers. Less than 1 week after planting, growers began a program of herbicide and insecticide treatments, which occurred almost every other day. This may account for the limited use of the Florida plots by birds. Bird use of the fields greatly increased after harvest, and the fish crow kill incident occurred shortly thereafter.

FMC Corporation attributed this kill to parathion, which was used near the test sites. However, the information presented to support parathion as the cause of death was insufficient. Analysis was submitted on only one bird, and no details were provided concerning the parathion use. At least one of the dead fish crows was originally reported to contain a small amount of carbofuran. Subsequently, however, the analysis of this specimen was reported below the detection limit. Although parathion was identified by gas chromatogram/mass spectrum analysis, several unknown peaks on the chromatogram of this specimen were not subjected to mass-spectrum analysis. When EPA did a proportional retention analysis on the position of these unknown peaks, at least one was retained at the expected position for 3-keto carbofuran (U.S. Environmental Protection Agency 1987e). However, confirmation of the identification of this unknown cannot be made without mass-spectrum analysis. As with the Field Studies 5 and 6, the analytical detection limit for carbofuran was not supported.

EPA could not verify the cause of death of the fish crows. Therefore, EPA did not use these data to estimate the potential impacts of granular carbofuran to birds.

Although the Florida study, which included raptor work, found no effects on raptors attributable to carbofuran, EPA did not use the information to estimate the potential for secondary mortality. The telemetry data showed little or no exposure of raptors to the treated areas. The researchers did, however, radio-tag nine red-shouldered hawks. This was an appropriate raptor species to study if exposure to treated areas had been established, because EPA believes that the red-shouldered hawk is highly susceptible to secondary mortality due to carbofuran. Also, some of the red-shouldered hawks were tagged relatively early in the study so that their locations could be tracked. However, six of the nine hawks radio-tagged had an "unknown" final status, which the authors could not explain.

6. Field Study 7

Flickenger et al. (1980) studied the effect of granular carbofuran applied to rice fields in Texas. This study monitored aerial broadcast application of 3G. The granules were not soil-incorporated and were available for consumption by birds feeding in the fields. Birds, fish, frogs, crayfish, earthworms, and nontarget insect fatalities occurred in rice fields after treatment with carbofuran. Specifically, four sandpipers were found dead following the 3G treatment. A red-winged blackbird was also found dead, and one was seen showing signs of intoxication. The study did not give a clear indication of the extent of treatments or of search acreage. EPA did not consider this study to be comparable to the other field studies because of the unknown extent of treatments and the lower percent of granule that was used to treat the fields. No quantitative analysis of this study could be performed because important information on the extent of treatments and the performance of carcass searches was not reported.

7. Estimate of Bird Mortality Rates in the Field Studies

The field studies resulted in birds killed from direct poisoning from carbofuran. Bird mortality per acre was estimated for each study except Flickenger et al. (1980) and the Florida portion of Field Study 6. These estimates were based on (1) mortalities confirmed by residue analysis, (2) carcasses in which carbofuran was strongly implicated as the cause of death, or (3) cases of probable sublethal poisoning in which a bird was judged as unable to recover prior to being subjected to other hazards such as predation. These bird mortality rates are probably underestimates because of problems associated with

carcass/search efficiency and removal of carcasses by predators and scavengers.

Estimates for the rate of secondary poisoning were not calculated because adequate data are not available. The conditions for evaluating secondary mortality in the available studies were even less standardized than those which studied direct mortality. While Field Studies 1 and 3 did provide definitive evidence that secondary mortality results from even the most conservative applications of granular carbofuran, field Studies 5 and 6, which attempted to study secondary mortality in a systematic way, did not observe such evidence. These studies did not provide adequate exposure of raptors to draw conclusions regarding carbofuran's ability to cause secondary mortality. The findings of Field Studies 1 and 3 enable EPA to conclude that granular carbofuran can cause secondary mortality. However, the studies did not systematically assess secondary mortality. Therefore, EPA did not attempt to estimate the rate of secondary poisonings that could be expected.

Although the field studies were performed at different application rates with different methods of application, all resulted in a certain number of granules being left unincorporated and available to birds. Also, each field study resulted in avian mortality and had one or more factors that led to the conclusion that the number of dead birds actually encountered in carcass searches may not have been a good indicator of the actual impact on birds. However, these studies can serve to illustrate the potential for comparative risk. In interpreting such studies, important considerations such as the habitat and ecology of the species exposed must also be considered.

For example, in comparing Field Study 1 to the other studies, EPA eliminated the mortality of the horned larks from the analysis. Field Study 1 resulted in 3.6 bird mortalities per acre from direct poisoning from carbofuran. However, 91.2% of the birds killed during this study were horned larks. Although the horned larks did not occur as a single flock on a single day, they appeared on the plots throughout the study. There are no LD50 data for tests conducted with horned larks. However, horned larks have been killed at several field study sites, thus demonstrating that carbofuran is toxic to horned larks. In addition, horned larks are likely to be exposed to granular carbofuran because they selectively use agricultural fields for feeding and nesting and they are abundant and occur in flocks.

Only Field Study 1 had a large kill of flocking horned larks. Therefore, EPA estimated the mortality rate for species other than horned larks when comparing the results of Field Study 1 to the other field studies. Discounting flocking resulted in a reduced mortality estimate of 0.3 bird per acre, which is similar

to the estimates of birds killed per acre in the other studies in which no single species predominated the body count. However, when the mortality attributable to the flocking horned larks is included, the estimate for overall mortality rate for the field studies ranged from 0.1 - 3.6 birds per acre.

EPA expects that large concentrations of birds, such as may occur in flocks or at migration times, do occur in corn fields. However, a kill of the magnitude observed in Field Study 1 may not frequently be reported from field studies. The very presence of study personnel in the area may discourage flocks of birds from utilizing fields, so that large kills of flocks of birds may only infrequently be observed during systematic surveys. The flock of fish crows in the Florida field study occurred only at the very end of the study when search activity and the grower's extensive pest management program activity had been substantially reduced.

EPA is concerned that flocks of birds may be regularly killed from carbofuran. However, EPA does not expect that flocking will occur each time carbofuran is used.

Field Studies 2 and 3 resulted in 0.1 and 0.7 bird mortalities per acre, respectively. Field Study 4 resulted in 0.4, 0.6, 0.9, and 1.4 mortalities per acre in Florida, Mississippi, South Carolina, and Louisiana, respectively. Field Study 5 resulted in 0.5 mortalities per acre in Illinois and 0.1 in Iowa. Field Study 6 resulted in 0.3 mortalities per acre in Texas.

The comparison of the data from the field studies was hampered by the lack of standardized field testing conditions. It is virtually impossible to ever achieve complete standardization in a field study because of the very different requirements of the various use patterns and application techniques used.

E. Reformulation Studies

FMC Corporation submitted two studies regarding the effect of a change in formulation on the mortality of European starlings. In the first study (FMC Corporation 1987a), birds were housed in pens and exposed to carbofuran contained in various carriers. These carriers contained 15% ai and included silica sand (the standard carrier), corn cob, and compacted granules. The colors of the granules varied, and the shape was either round or angular. The lowest survival rate was with the standard Furadan¹ 15G commercial granule. The study concluded that mortality was reduced by 67% for formulation 6 (angular,

¹Registered trade mark

white core), 61% for formulation 15 (round, painted black core), and 48% for formulation 10 (round, amber-colored core). All of these formulations were red, silica sand granules.

EPA's review (U.S. Environmental Protection Agency 1987c) of this study indicated that the study had design, execution, and reporting deficiencies and could not be used in the analysis. Some of the problems with this study included small sample size and small differences in mortality observed in the studies. European starlings were the species studied and are one of the least sensitive species to carbofuran. Ecological factors including grit consumption, and certain starling behavioral factors were not controlled for in this study and could have substantially affected conclusions regarding the hazard to birds from the different formulations.

As a result, the study did not show definitive differences in the mortality of Starlings which could be solely attributed to exposure to different formulations. Although the standard Furadan formulation resulted in more apparent mortalities than some of the experimental formulations, this effect was not definitively established to be solely the result of reformulated granules.

In the second study (FMC Corporation 1987b), carbofuran was applied to pens as a 7-inch or T-band using minimum carbofuran application rates. The formulations that had shown promise in an other study (FMC Corporation 1987a) were used.

EPA's review of this study (U.S. Environmental Protection Agency 1987b) indicates similar design and execution problems as with the previous study (FMC Corporation 1987a). EPA agrees with the conclusions of the study, which indicated that the study could not detect significant differences in mortality among treatments. EPA also agrees that mortality results were confounded by a large number of missing birds and poor weather conditions. Since the studies were initiated outdoors in late October in Wisconsin, it is not surprising that inclement weather disrupted the study. The authors reported that 26 out of 109 total mortalities occurred on the last 2 days of the study and were likely due to inclement weather. EPA cannot verify how many of these mortalities would not have occurred had the birds not been exposed to treatments as well.

The results of this study contradict the conclusions of the companion study (FMC Corporation 1987a) regarding the potential for reduced toxicity of the experimental granules. Experimental granules did not appear to be less attractive to the birds when the mortality data (which excludes the missing birds and the birds dying during the last two days of the study) were used as the judgment criteria. The experimental granules (formulations 6, 10, and 15) were almost always accompanied by equal or greater

percentages of mortality than the standard Furadan granule (formulation 1).

Because of the deficiencies in both studies, EPA could not use these studies in its hazard assessment.

F. Bird Kill Incidents from Direct Poisoning

In the previous sections, EPA assessed the risk to birds based on the acute toxicity of carbofuran, exposure, and field studies. Additionally, EPA has documentation of a substantial number of bird kill incidents associated with carbofuran. The occurrence of these incidents confirms that carbofuran presents a substantial risk to birds.

EPA's assessment of these bird kills (U.S. Environmental Protection Agency 1987e) considered only those incidents in which carbofuran was clinically diagnosed as the cause of mortality or was strongly implicated. In most cases, site inspection and environmental and/or bird carcass analysis were conducted to determine the levels of residues and the cause of death. Anecdotal reports or incidents of established misuse were not considered. Incidents of misuse may have occurred in some bird kill incidents but were not established.

EPA received documentation for over 40 bird kill incidents (Table II-8), excluding those occurring from secondary poisoning. These kill incidents do not include those that resulted from the field studies. These kills involved more than 30 different species of birds. The most commonly affected type of bird was waterfowl. However, songbirds including Lapland longspurs, several species of sparrows, and robins, marsh and shorebirds, and other types of birds were also affected.

The number of individuals involved in any single kill incident ranged from 1 to over 2000 birds. California reported the most number of kills, which totaled 25 and occurred in rice. (California has an organized system in place for the reporting of bird kills, which may be the reason that most of the kill reports came from California.) However, kills were reported in other areas including Maryland, Illinois, Indiana, Wisconsin, New York, and Canada.

As indicated, rice was the use site for which the most number of kill incidents were reported. Six were reported for corn, four for turnips, and two for potatoes. (Although granular carbofuran is not registered for use on turnips or potatoes in the United States, it is registered in Canada.) Other sites had one kill incident reported.

Table II-8. Summary of Bird Kill Incidents from Direct Carbofuran Poisoning

<u>Site</u>	<u>Formu- lation</u>	<u>Occurrence</u>	<u>Location</u>	<u>Species</u>	<u>Number of Birds</u>
Corn	15G	August 1983	Maryland	Waterfowl	200
		February 1984	Illinois	Canada Goose	Not known
		June 1986	Indiana	Songbird	12
		? 1987	New York	Robin	3
	10G	? 1972	Wisconsin	Songbird	11
		? 1973	Wisconsin	Songbird	3
		May 1979	New York	Robin	10
Corn/ Soybeans	15G	May & June 1983	New York	Waterfowl	25
				Blue Jay Grackle Killdeer	
Pineseed orchard	10G	? 1974	-----	American Robin	22
				Eastern Bluebird	1
Potatoes	15G	June 1986	New York	Passerines	20
	10G	November - December 1974	Canada	Widgeon Pintail	80
Rapeseed ¹	10CR ²	May 1984	Canada	Lapland Longspur	> 2000
Rice	5G	April - June 1984	California	Mallard Duck	5
			California	Mallard Duck	4
				Blue-winged Teal	
			California	Cinnamon Teal	
			California	"Dabbler" Duck	5
			California	"Dabbler" Duck	4
			California	"Dabbler" Duck	21
		April 1985	California	"Dabbler" Duck	4
			California	Mallard Duck	16
			California	"Dabbler" Duck	2
			California	"Dabbler" Duck	4
			California	Mallard Duck	2
			California	"Dabbler" Duck	67
		October 1985	California	"Dabbler" Duck	35 - 50 ³
			California	Duck	40 - 50 ³
			California	Duck	6 - 7 ³
				Coot	5 ³
		April 1986	California	Duck	25
			California	Mallard Duck	1
			California	Mallard Duck	4
			California	Mallard Duck	4
				Shorebird	
				Cinnamon Teal	

Table II-8. Summary of Bird Kill Incidents from Direct Carbofuran Poisoning (cont'd)

<u>Site</u>	<u>Formu- lation</u>	<u>Occurrence</u>	<u>Location</u>	<u>Species</u>	<u>Number of Birds</u>
Rice (cont'd)	5G	April 1986	California	Mallard Duck	1
			California	Cinnamon Teal	14
			California	Mallard Duck	1
		October 1986	California	Mallard Duck	150 ³
				Pintail	
				Widgeon Duck	
		April 1987	California	Mallard Duck	2
			California	Mallard Duck	1
			California	Mallard Duck	1
Turnips ¹	10G	? 1975	Canada	Green-winged Teal	1100
			Canada	Pintail Duck	50
		? 1977	Canada	Mallard Duck	50 - 60
				Pintail Duck	
		December 1973	Canada	Mallard Duck	500 - 1000
		June 1986	Canada	Savannah Sparrow	

¹ Carbofuran is not registered for use on this crop in the United States.

² 10 percent corn cob granule.

³ These kills may have been a misuse or resulted from carbofuran applied earlier in the year.

⁴ Although only one duck was analyzed and included in the table, 25 ducks were actually killed.

Kill incidents were reported throughout the year, but primarily in the use season that normally occurs from April through June. However, kill incidents were reported for rice in the fall in California, which included the death of northern harriers and red-tailed hawks. Wildlife officials in California have not been able to conclusively explain the rice-related kills in the fall, since the rice is treated much earlier in the year. It has been suggested that individuals could be misusing carbofuran to kill crayfish, which burrow into the levees of a rice field. However, the possibility of persistence from an earlier use on the crop was not explored. Earlier rice crop uses had killed birds in California. Whitehead (1975) suggested that granular carbofuran applied to turnip fields continued to kill waterfowl by the thousands throughout the year. However, it was unclear whether Whitehead was reporting a misuse or legal application of the pesticide.

In reviewing the available information, EPA concluded that bird kill incidents resulting from the application of carbofuran according to label directions occur throughout the United States.

It is likely that the number of bird kills that have been reported underestimate the extent of the actual hazard. There is no systematic or reliable mechanism for accurate monitoring and reporting of all wildlife kill incidents to EPA.² EPA relies heavily on the incident monitoring efforts of the states. There is considerable variability among states regarding the extent of effort and adequacy of their respective programs. Only a few states have personnel trained and equipped to respond to kill reports and to conduct the thorough investigation necessary to determine the pesticide and application rate used and whether label directions were followed. In addition, few states regularly report bird kill incidents to EPA. Stone and Gradoni (1986) also outlined factors contributing to the underreporting of wildlife incidents.

EPA received documentation of examples of the difficulties some States face in investigating wildlife kill incidents (Indiana Department of Natural Resources 1986, California Fish and Game 1986c). In one case, only 12 district biologists cover the entire state. With such limited coverage, it is not always feasible for a biologist to immediately get to a farm where the farmer promptly reported a bird kill incident. Investigators could not make a definitive analysis of the cause of death because the tissues of the birds had become too decayed. Soil samples were obtained from the field, but an analysis was not performed because biologists could not show that the application

²EPA is working toward the development of a more effective and reliable system for the reporting and management of information concerning such incidents.

was a misuse. The soil samples were discarded. In another case it was reported to the State that farmers were not reporting all wildlife losses.

Birds may not be found because predators carried the carcasses away from the site. Some birds tend to go into brush or cover when dying and may not be noticed. Should dead birds be found, the observer may not attribute the deaths to an insecticide application. Field evidence indicates that carbofuran may cause bird mortality 60 days after it was first applied. Thus, a farmer or other observer not familiar with the use site history may not attribute the death to carbofuran application. Even if a person does suspect that a bird may have been poisoned, the individual may not know to whom to report the incident, may not believe that it is important to report it, or may indeed believe that there is some liability associated with reporting.

The problems associated with the reporting of bird kills is even greater for small and more inconspicuous songbirds. Many smaller birds do not form large conspicuous flocks, and smaller carcasses disappear more quickly than larger ones. As a result, small dead birds are even less likely to be noticed than larger birds such as waterfowl.

Public observation is important in the rate of bird kill reporting. EPA believes that the many kills that were reported for golf courses as a result of diazinon application reflect in part the regular presence of the public in a wide-open area. This is in direct contrast to the sites for which carbofuran is registered. These sites do not have the degree of public visitation that golf courses do. Fewer people are on or near these sites, and bird kills are less likely to be observed. For example, in a bird kill resulting from secondary poisoning from carbofuran, a bald eagle was discovered dead at the base of its nest in a heavily wooded area. The bird was discovered only because its metal leg band was detected by an individual searching for Civil War artifacts with a metal detector (Patterson 1986a).

EPA concludes from the analysis of bird kills that the risk to birds is widespread from use of carbofuran according to label directions. EPA has determined that the extent of the risk is even greater than estimated because of the many problems associated with the reporting of bird kills.

G. Bird Kill Incidents from Secondary Poisoning

EPA also has information concerning bird kills resulting from secondary poisoning of birds from carbofuran. Only those kills in which carbofuran was strongly implicated were considered.

EPA believes that the ability of granular carbofuran to cause secondary poisonings is an important factor in the cumulative avian risk. This is especially true because of the unique ecology of raptors. They occupy an important niche in the food chain, performing important natural population control functions for vertebrate populations. The scavenging activities of some raptors and other predacious birds are, likewise, important functions of the species. Because of the problems inherent in studying raptor populations, however, it is very difficult to effectively monitor secondary poisoning.

Table II-9 summarizes the secondary poisonings that occurred as a result of the field studies. Details concerning these incidents are discussed in Section C of this chapter.

For example, two red-shouldered hawks were found in Field Study 3 (Balcomb 1983). A total of 96.6 ug of carbofuran was extracted from one bird. The second was severely intoxicated but rescued by researchers who allowed the bird to recover safely. The total toxicant extracted represents between 2.5 and 59% of the published LD50 values for wild bird species, ranging from 0.24 mg/kg to 5.5 mg/kg. Passerines recovered from the same field contained between 30 and 99.4% of the published LD50 range or from 32.2 to 172.9 ug carbofuran per bird. By feeding in corn fields treated with 10G carbofuran at 1 lb ai/A using in-furrow application, these birds acquired doses much in excess of the amount required to kill adult hawks.

Table II-10 summarizes the incidents of secondary poisoning reported by various sources. Stone (1985) reported that an adult female red-tailed hawk was found dead not far from her nest; the hawk contained 0.06 ppm carbofuran in the liver. The stomach contents of the hawk, which included the remains of a European starling and two voles, were screened for nine other toxic pesticides, but none were detected. The necropsy report found "no signs of disease or trauma" indicating no other obvious cause of death such as shooting, parasites, or disease.

The secondary poisoning of a northern harrier after 5G application to a rice field was reported (California Fish and Game 1986a). The hawk was found paralyzed and dying. Crop contents included duck viscera, flies, maggots, and carbofuran at a level of 64 ppm. Brain cholinesterase was inhibited by 84%.

A red-tailed hawk was found dead (Virginia Polytechnic Institute 1986b). The carcass contained 0.107 ppm carbofuran.

Two red-tailed hawks and a northern harrier were killed coincidental to a large waterfowl poisoning in California rice fields. Although misuse has been suggested as the cause,

Table II-9. Secondary Bird Mortalities in the Field Studies

<u>Field Study</u>	<u>Application</u>	<u>Species</u>	<u>Description</u>
1	15G and 10G to corn	raven	- Two ravens contained residues up to 8.1 ppm and 38 granules. - Another was found exhibiting symptoms of poisoning but did not die.
		northern harrier	- Contained up to 21.8 ppm carbofuran and 23 granules - Another was found exhibiting symptoms of poisoning but did not die.
		short-eared owl	- No analysis reported.
3	10G to corn	red-shouldered hawk	- Female found intoxicated after feeding on small mammals and birds. - Bird was sacrificed -- gut contained 47 ug and gastrointestinal tissue 49.6 ug carbofuran. - Male poisoned but recovered.
4	10G to pine-seed orchards	loggerhead shrike	- Possible carbofuran poisoning. - One dead and one moribund.
6	10G and 15G to corn	Harris hawk	- One found dead near treatment fields but did not contain granules or residues. However, the analysis may not have been conducted at the appropriate sensitivity level.

Table II-10. Summary of Bird Kill Incidents from Secondary Carbofuran Poisoning

<u>Month and Year of Occurrence</u>	<u>Location</u>	<u>Site</u>	<u>Species</u>	<u>Description</u>
April 1984	New York	Unknown	red-tailed hawk	- Adult female found dead near nest with 0.06 ppm carbofuran in the liver and remains of a starling and voles in the stomach.
October 1985	California	Rice	northern harrier	- 64 ppm carbofuran recovered from crop contents, including flies, duck viscera, and maggots. - 84 percent brain cholinesterase inhibition.
April 1985	Virginia	Corn	bald eagle	- 1 adult male dead at base of active nest with 58.6 percent brain acetylcholinesterase inhibition. Gastrointestinal tract contained 0.64 ppm carbofuran. - 1 dead eaglet in nest along with pigeon and grackle remains. - Cornfields nearby treated with carbofuran. Dead and dying pigeons and other birds found nearby.
May 1985	Virginia	Corn/ Soybeans	bald eagle	- 1 sick and paralyzed bird found near fields--carbofuran suspected. Another eagle found dead nearby.
April 1985	Virginia	Corn	bald eagle	- 1 found dead in cornfield treated with 15G at 2.7 lb ai/A. - Eagle's brain exhibited 60 percent acetylcholinesterase depression. The esophagus contained 82 ppm, the stomach 0.067 ppm, and the duodenum 1.1 ppm carbofuran.
May 1986	Virginia	Corn	bald eagle	- 1 found near field treated with 15G. The bird was too decomposed for analysis.
June 1986	Virginia	Corn	red-tailed hawk	- 1 found dead. Contained 0.107 ppm carbofuran.
October 1986	California	Rice	red-tailed hawk	- 2 found dead during larger waterfowl kill incident.
			northern harrier	- Found in the incident above.

California officials have not definitively established this incident to have resulted from a misuse (Littrell 1986).

A red-shouldered hawk is small in comparison to a bald eagle, the hawk weighing 19 and 13.5% of the body weights of immature and adult female bald eagles, respectively. Immature and adult eagles have been killed by feeding on birds and mammals in or near granular carbofuran-treated corn fields.

Six known or potential secondary poisoning incidents occurring from 1985 through 1987 were reported from the population of bald eagles along the floodplain farms of the lower James and Rappahannock Rivers in Virginia. These areas are planted in corn, soybeans, peanuts, and other crops treated with carbofuran. Both immature and adult eagles have been poisoned by feeding on birds and/or mammals in or near fields treated with granular carbofuran. The risks of exposure of bald eagles is greatest during the nesting season because this time coincides with spring at-planting applications of carbofuran. Several documented cases have been reported (Table II-10).

In the first incident, granular carbofuran produced acute poisoning of rock doves (pigeon) after carbofuran application to fields of corn (Patterson 1986a, U.S. Fish and Wildlife Service 1986a and 1986b). An adult male bald eagle was killed from secondary poisoning after feeding on rock doves on this farm. The adult was found at the base of the nest within 1 mile of the recently treated corn field. The adult was found with 58.6% brain acetylcholinesterase inhibition. The gastrointestinal tract contained 0.64 ppm carbofuran, small bones, and rock dove feathers.

Evidence found in the nest suggests that the same adult had brought the rock doves back to the nest, where a dead eaglet was found along with rock dove and grackle remains. A live adult female and two live eaglets were also present. The dead eaglet, however, was too decomposed to analyze. Although a definitive cause of death was not established for the eaglet, the bird remains found in the nest suggest possible secondary poisoning of the eaglet.

A third bald eagle was found a few miles away from the other two secondary eagle poisoning incidents. The eagle was sick but alive and was taken to a wildlife rehabilitation center and treated. The bird was paralyzed and exhibited signs of cholinesterase poisoning caused by carbofuran or other cholinesterase-inhibiting pesticides. Based on a treatment and analysis report (Virginia Polytechnic Institute 1985, FMC Corporation 1986e Patterson 1986a), EPA regarded this bird secondarily poisoned from carbofuran application to nearby corn/soybean fields. Atropine was administered, and the bird was allowed to recover. EPA concluded that if the eagle had not been

found, it would probably not have survived in the wild. A fourth eagle was found dead nearby.

A fifth eagle was found dead in a recently planted corn field treated with 15G (Patterson 1986b; U.S. Fish and Wildlife Service 1986c, 1986d, 1986e, and 1986f). The granules were soil incorporated at 2.7 lb ai/A. The eagle's brain exhibited 60% acetylcholinesterase depression. The esophageal contents contained 82 ppm carbofuran, and the stomach and duodenum contained 0.067 and 1.1 ppm carbofuran, respectively. At first, the death of the bird was attributed to the eagle feeding on a carbofuran-contaminated raccoon. The raccoon carcass was found in the field, and other eagles were found actually feeding on the carcass. Upon necropsy, no evidence of raccoon or hair was found, leaving open the possibility that other contaminated food sources could have been ingested.

A sixth bald eagle was found 30 feet from a recently planted corn field that had been treated according to label directions with 15G (Patterson 1986c). The bird was too decomposed to analyze.

Raptor biologists have based estimates of the mortality rate of Chesapeake Bay Regional bald eagle populations on returns of banded Chesapeake birds and the survival rates for nesting populations in Maine. The analysis shows that only 3.6% of nonsurviving Chesapeake Bay eagles "have been found dead and reported to bald eagle researchers" (Cline 1986). Cline and other experts assert that the remainder of the eagles dying in the wild are "presumably scavenged by other animals or the carcasses are hidden or located in remote areas and decompose before being found by humans" (Cline 1986). This assertion is supported by predator-scavenger carcass removal studies in agricultural fields (Balcomb 1986), although the latter work is more pertinent to smaller songbird carcasses.

As a conservative estimate, EPA attributes three eagle deaths per year to carbofuran secondary poisoning in the James River breeding population. This population is closely monitored by biologists at the College of William and Mary, Williamsburg, Virginia. Based on a description of the three distinct phases of this population (Byrd 1986), three pesticide-related deaths represent about 6% of the breeding population on the James River in the spring of 1986.

EPA expects that these incidents comprise only a few of the secondary poisoning deaths that are caused by granular carbofuran. The problems associated with the reporting of bird kills are even greater with secondary poisoning incidents involving predatory birds such as raptors.

There have been numerous eagle deaths reported in eastern Maryland since spring of 1988. Many of these deaths are apparently attributable to deliberate misuse of carbofuran. Analyses and investigations are still being conducted by both the Fish and Wildlife Service and EPA. As the investigations are completed, EPA will consider the findings in determining what action to take concerning carbofuran.

H. Population Effects

EPA is concerned with not only the acute poisoning of individual birds from carbofuran granules, but also the potential impact of this acute mortality on declining populations of birds. The overall population impact of acute mortality from carbofuran in agricultural use may appear to be negligible for abundant species such as blackbirds, including red-winged blackbirds and grackles, and horned larks. However, acute mortality from secondary poisoning may have marked impact in a small population of a less abundant species such as eagles, hawks, and other birds of prey. The potential additive effect may be especially significant for species facing other pressures such as habitat loss. Acute mortality may also pose a threat to species that have low reproduction potential, which could further inhibit recovery from pesticide poisonings. Such species often are less resilient and the additive effects of acute mortality from pesticide poisoning on their populations may be even more important than populations of more abundant species.

Species exposed to agricultural uses of granular carbofuran exhibit a wide range of reproductive potential (Table II-11). Certain waterfowl, for example, have a high reproductive potential compared with certain birds that are endangered or declining and may produce only one, two, or a few eggs per clutch. Other birds such as the Aleutian Canada goose, an endangered species identified as jeopardized by carbofuran use by the Office of Endangered Species (OES), U.S. Department of the Interior, may lay several eggs per clutch but produce only one clutch per year.

Secondary poisoning from carbofuran has occurred and is of concern because birds of prey often produce only a few eggs per year and reach sexual maturity at a comparatively late age. Welty (1975) states that such species must have a "compensating long life expectancy" in order to maintain reproduction potential. Each fatality of a breeder or potential breeder in this type of species has a greater proportional negative influence on population growth or stability, and acute mortality is probably an important factor in regulating population levels of these species.

Table II-11. Reproduction Potential of Selected Species Likely to be Exposed to Carbofuran

<u>Species</u>	<u>Eggs per Brood</u>	<u>Normal No. of Broods per Year</u>	<u>Expected Maximum Annual Reproduction Potential per Female</u>
Fulvous whistling-duck	6 - 16	1	6 - 16
Mallard	6 - 10	2	12 - 20
Black duck	6 - 12	2	12 - 24
Green-winged teal	8 - 12	1	8 - 12
Northern pintail	7 - 10	1 - 2	7 - 20
Wood duck	8 - 14	2 - 3	16 - 42
Canvasback	6 - 10	1 - 2	6 - 20
Ring-necked duck	6 - 12	1 - 2	6 - 24
Northern shoveler	8 - 14	1 - 2	8 - 28
* Aleutian Canada goose	1 - 12	1	1 - 12
Brant	1 - 10	1	1 - 10
American coot	7 - 16	1	7 - 16
Sandhill crane	2	1	2
* Whooping crane	2	1	2
Woodcock	3 - 4	1	3 - 4
Northern bobwhite	12 - 18	1 - 2	12 - 36
Mountain quail	6 - 20	2	12 - 40
California quail	12 - 16	1	12 - 16
Ruffed grouse	6 - 15	Multiple	> 6 - 15
Mourning dove	1 - 2	1 - 5	1 - 10
Red-shouldered hawk	2 - 4	1	2 - 4
* Bald eagle	2 - 3	< 1	2 - 3
American Kestrel	4 - 5	1	4 - 5
Screed owl	4 - 5	1	4 - 5
Northern flicker	4 - 8	Multiple	> 4 - 8
American robin	4 - 5	2	8 - 10

* Listed as an endangered species according to the Endangered Species Act.

EPA does not attribute the decline of any species discussed in this section solely to the use of granular carbofuran. Many factors, such as diseases, climate, weather, and habitat loss, contribute to bird population dynamics. In addition, it would be difficult to definitively ascertain that a population decline was solely attributable to any one cause, pesticide or otherwise. EPA is particularly concerned about carbofuran application in areas where certain species of birds are declining because carbofuran may be one of several additive factors that contributes to a population's decline.

1. Computer Models

As indicated previously, secondary poisoning has occurred in certain field studies and has also been reported as separate kill incidents. A review of the reported kill incidents and field studies indicate that secondary poisoning may be observed when numerous carcasses are involved in bird kills. Perhaps the predators are attracted to the site by the bodies visible on the surface of fields.

The evaluation of field studies in Florida and Texas (FMC Corporation 1986a) suggested that it may be very difficult for EPA to quantify the impact of acute secondary poisoning on raptors because of the difficulties inherent in the study of the ecology of avian predators. These include inadequate habitat sampling (Bystrak 1981) and difficulties in observing behavior and the fact that these species often lack sufficient density (Robbins et al. 1986, FMC Corporation 1986a) in a study area to enable an adequate statistical design to study quantitative impact.

Because of the difficulties associated with studying the impact of secondary poisoning on raptors, EPA used computer models to illustrate potential impacts on small populations of birds. The bald eagle population of the lower James and Rappahannock River flood plains was the population that was modeled. EPA did not use this model to predict the impact on bald eagle populations from carbofuran. The model was simply used to illustrate potential impacts from secondary poisoning on small populations of birds.

EPA used a stochastic model because such a model incorporates the effect of "chance," an important factor in small populations. For example, in a population of two males and two females, an expected mortality rate of 50% can allow for a several-fold increase in population, if by chance one male and one female die, leaving a pair to reproduce. If by chance both deaths occur in the same sex, the small population could disappear.

"Chance" can also play a role in the number of young each female produces and the sex of those young. Since the effect of chance in a small population cannot be ignored, deterministic models are less useful for modeling small populations than stochastic models.

Grier (1980) modeled bald eagle populations and found that survival rate is a critical factor affecting eagle populations. The model implied that management of nesting habitat with the goal of maximizing reproduction will not guarantee population growth or even stability unless accompanied by an adequate rate of survival. Swenson et al. (1986) in his 10-year population study of bald eagles concurred with Grier's conclusion and stated that "unless bald eagles in the YU (Yellowstone Unit) . . .," a local population, ". . . had extremely high survival, reproduction was not adequate to sustain the breeding population."

EPA used Grier's model to simulate the 10-year fate of the floodplain breeding population of bald eagles along the Lower James River, Virginia. The James River population of bald eagles has three distinct phases during which different numbers of eagles are present. In the winter phase from October through February, approximately 60 to 70 nonbreeding birds were present in 1985. By February 1986, most of these birds had departed, leaving a spring breeding population of nine breeding pairs. By April 1, small numbers of southern migrants began to appear. The numbers of southern migrants steadily increased until May 1 and may have included 40 additional birds. A June census indicated over 70 birds and by July the southern migration peaked with perhaps 100 to 125 birds concentrating in this small area for the summer phase (Byrd 1986).

The observed rate of secondary poisonings of bald eagles on the James River in 1985 may have been as high as 8.3% for birds of the year and 6.5% for older birds. These percentages may be underestimates because the number of pesticide-related deaths is based on the observations made in 1985 when the population may have been smaller than in 1986, which was used as the "baseline" year. If a smaller 1985 population is used as the baseline, the percentages of acute pesticide mortality would be higher than those indicated above.

EPA focused on a resident breeding population by simulating 10 years of growth in this population. This was done because resident breeders are the most important birds to the overall Chesapeake Bay population and because these birds are present when carbofuran is used at-planting in Virginia. A 10-year baseline population was established using inputs biased toward maximizing the breeding potential of the existing spring breeding population (Table II-12). Forty-five simulations of baseline and

pesticide cases were run to evaluate the effects of 0%, 2%, 5%, 7%, and 10% additional mortality due to secondary poisoning.

Grier made the following assumptions, which the EPA also used in its model:

- (1) Breeding is seasonal and basically synchronized in the population. All birth or hatching occurs within a relatively short period.
- (2) Since monogamous breeding is used in the simulations, the number of breeding pairs is limited by the sex with the least number of adults.
- (3) Members of potential pairs actually breed.
- (4) No inbreeding problems exist.
- (5) No density-dependent effects limit the population growth.
- (6) All mortality occurs outside the reproductive season.
- (7) Male and female mortality rates are the same.
- (8) Mortality rates are constant (within random limits) for animals older than 1 year.
- (9) The mortality and reproductive rates do not change significantly over time.

Several additional factors and assumptions specific to EPA's use of Grier's model were made. Most of these make the population model conservatively biased toward minimizing the effect of the pesticide because they also minimize acute mortality in general.

- (10) The reproduction and survival rates are at the upper limit suggested by eagle biologists (Grier 1980). As a result, the potential for population growth is maximized, which compensates for the effect of acute mortality.
- (11) Except for first-year birds, all age classes are equally likely to be subjected to pesticide-induced mortality. Thus, contribution of breeder mortality to the outcome is thus minimized, which compensates for the potential pesticide effects in the short term because birds take 5 years to reach sexual maturity.
- (12) Pesticide-induced acute mortality is added to the normal mortality rate (baseline). The pesticide mortality is held constant over 10 years based on a constant availability of lethal pesticide levels in the eagle diet and does not increase as the population increases. This assumes no action has been taken to reduce pesticide availability for the eagles.
- (13) The sex ratio is 1:1, which maximizes breeding potential and compensates for the potential effects of the pesticide.

Table II-12. Baseline Population, Reproduction, and Survival Rates Used for Bald Eagle Population Model

The baseline population for the Lower James River, Virginia Bald Eagle population model contained 9 pairs of breeding eagles (9 male + 9 female = 18 breeding adults) in the spring of 1986. Age at first breeding was 5 years.

	Young Produced/Year
Percent of adult females producing 0 young = 20 *	0
Percent of adult females producing 1 young = 20 *	2
Percent of adult females producing 2 young = 56 *	10
Percent of adult females producing 3 young = 4 *	<u>1</u>
Total Young of Year	13
Initial equalization of sexes of birds of year ... 6 male, 6 female*	
Existing birds 1 year or older	5 male, 5 female*
Existing birds 2 years or older	4 male, 4 female*
Existing birds 3 years or older	3 male, 3 female*
Existing birds 4 years or older	11 male, 11 female*
(4 years or older category includes 2 male, 2 female immatures, plus 9 male and 9 female breeding birds)	
Annual survival rate of first-year birds	70 percent*
Annual survival rate of older birds	90 percent*
Rates of pesticide-induced mortality (1985 figures)	
"Older" birds (3/46)	6.5 percent
Young of year (1/12)	8.3 percent

*Indicates a model input.

Figure II-1 represents the effect of baseline and pesticide-induced mortality on birds at least a year old. The potential impact near the observed rate of pesticide-induced poisonings (5% to 7%) appears to be a flattening of the growth curve. This was particularly evident when the model added increasing pesticide-induced mortality rates and the means and positive and negative standard deviations of the resulting populations were plotted against the baseline population mean $\pm$ standard deviation. Rates of pesticide-induced mortality higher than those observed in Virginia caused a decline in the numbers of breeding birds.

When the effect of pesticide-induced mortality on birds less than 1 year old was evaluated, the results suggested that the influence of pesticide mortality in this age class does not substantially affect the short-term outcome.

EPA concluded that at the rate of pesticide-related mortality observed in Virginia and under very favorable survival and breeding conditions, the small breeding population of bald eagles on the lower James River could sustain itself, but may not increase. If less than the maximum breeding potential is achieved, or if other factors result in decreased survival below 90% annually for birds older than 1 year, the population of breeding birds will probably decrease, even if the pesticide-induced mortality remains at or below 7%.

2. Declining Populations of Birds

EPA is concerned about the impact of carbofuran on endangered species and other declining species that are exposed by the agricultural uses of carbofuran.

a. Endangered Species

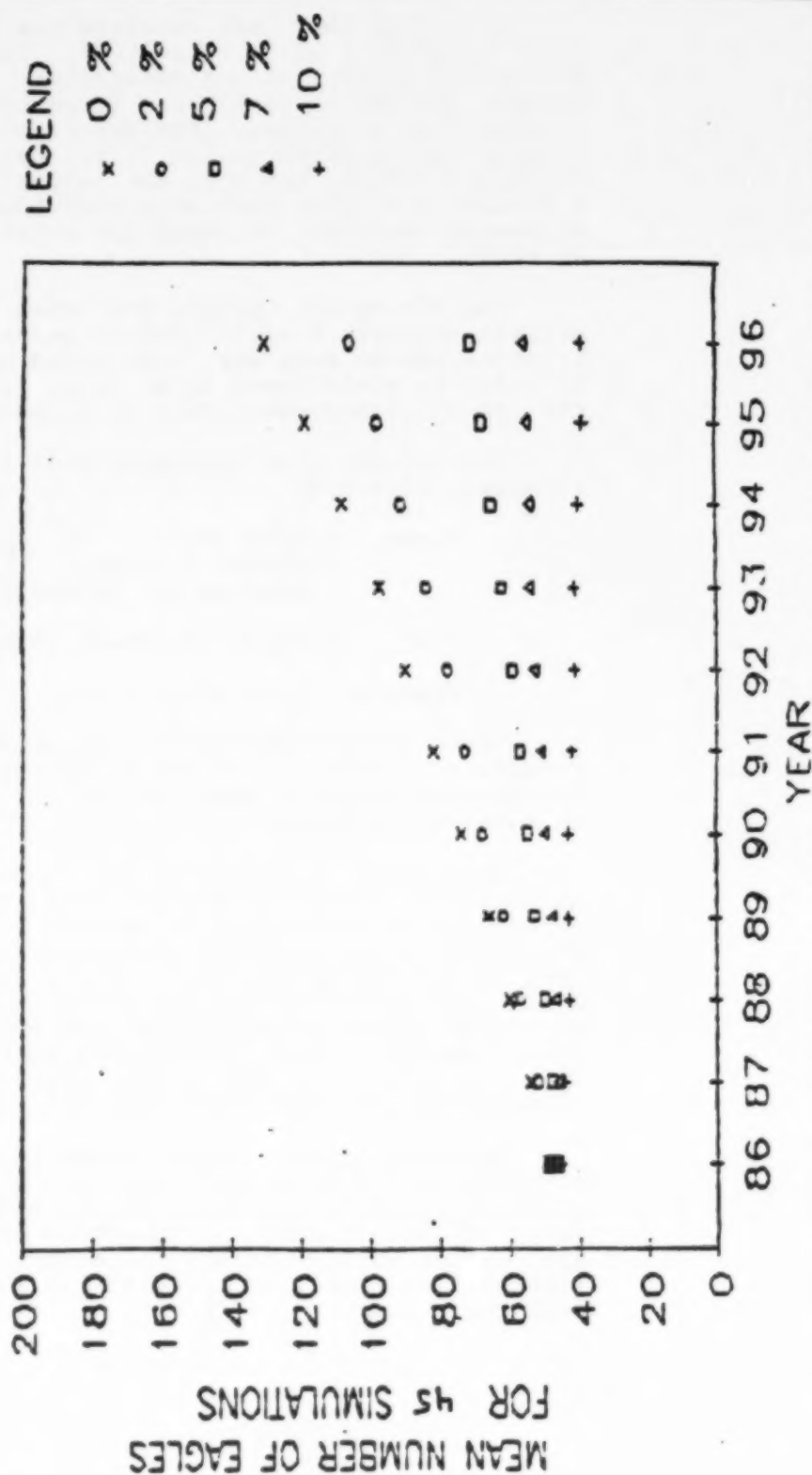
In accordance with Section 7 of the Endangered Species Act of 1973, EPA requested a formal Biological Opinion in consultation with the DESHC in 1981. DESHC responded, but as a result of the receipt of new data concerning secondary poisonings, EPA requested another Opinion from DESHC.

EPA received a draft Biological Opinion on June 12, 1986. EPA and FMC Corporation representatives met with DESHC in their Region 5 Regional Office on December 9, 1986 to discuss the Section 7 process and the new procedures that were in effect. DESHC also met with FMC representatives in Washington, D.C. to discuss the draft Opinion.

The new procedures presented the opportunity for both FMC Corporation EPA to submit comments on this draft for DESHC consideration. DESHC received the EPA's comments on 6 April 1987.

Figure 11-1

EFFECTS OF PESTICIDE-INDUCED MORTALITY ON BREEDING BALD EAGLES OF THE LOWER JAMES RIVER, VIRGINIA: A TEN -YEAR SIMULATION MODEL



On 6 July 1987, EPA received the final Biological Opinion (U.S. Department of Interior 1987), describing the impact to endangered species as two categories. The first is "jeopardy," whereby the use of carbofuran is believed to threaten the existence of a species. The second category describes the finding that a given action (i.e., use of carbofuran) "may adversely affect, but will not jeopardize" a given species. Such a finding indicates that some individuals may be killed or adversely impacted, but that the survival of the species is not at stake.

The Biological Opinion indicated that the Attwater's greater prairie chicken, Aleutian Canada goose, Aplomado falcon, and Kern primrose sphinx moth are jeopardized by the use of carbofuran. In order to avoid jeopardy to these species, DESHC indicated that the use of carbofuran should be eliminated in certain areas.

The Opinion also indicated that the following may be adversely affected:

- Birds - bald eagle
 whooping crane
 Mississippi sandhill crane
- Fish - Pecos bluntnose shiner
- Mammals - Utah prairie dog

DESHC recommended monitoring selected field applications of carbofuran within the ranges of affected species. DESHC also recommended specific measures for the individual species that may be adversely affected.

Bald eagle: Because of the documented losses of bald eagles in Virginia, DESHC recommended that the use of granular carbofuran be prohibited in certain areas of the Delmarva Peninsula (i.e., portions of Delaware, Maryland, and Virginia east of the Chesapeake Bay). Also, DESHC recommended that applicator certification and training include information on the potential impact of carbofuran and other pesticides to this and other species. DESHC anticipates up to three birds per year may die from carbofuran use in that area. DESHC also indicated that covering up granules after application should be stressed.

Whooping crane: DESHC recommended that an Information Bulletin on the whooping crane and on proper application of granular insecticides be developed and distributed throughout the range of this species. Also, DESHC claimed that in-furrow application within the species range should reduce the hazard. DESHC anticipates that two cranes a year will be killed from carbofuran use.

Mississippi sandhill crane: A county restriction along with in-furrow application in that county was recommended to minimize the hazard caused by carbofuran to this species. No mortality is anticipated, but DESHC predicts that two cranes per year will be sublethally affected by granular carbofuran consumption.

DESHC concluded by indicating that a consultation should be reinitiated if (1) any new uses are proposed, (2) DESHC lists new species or critical habitat which may be affected by granular carbofuran use, or (3) mortalities occur that are inconsistent with the number that DESHC has anticipated and that affect species not covered in the Opinion.

b. Other Declining Species

EPA also is concerned about other species that have unstable or decreasing populations. Table II-13 lists nongame migratory bird species for which "some evidence of unstable or decreasing population trends in significant portions of their range in the United States" exist (U.S. Fish and Wildlife Service 1982). Species identified by the U.S. Fish and Wildlife Service as threatened or endangered species are not included in this list. Species are included in the listing because of population declines, small population size, and/or restricted habitat.

This list is partially compiled by Robbins et al. in the BBS, the most comprehensive source of quantitative data for the majority of nongame migratory birds in the United States. However, major avian groups such as hawks are not adequately covered by the BBS (U.S. Fish and Wildlife Service 1982, Bystrak 1981, Robbins 1985). As a result, the U.S. Fish and Wildlife Service also consulted the National Audubon Society's "Blue List" (Tate 1981), the U.S. Fish and Wildlife Service DESHC "WATCHLIST," the National Audubon Society Magazine's Christmas Bird Counts, and State endangered and threatened species lists. These are lists of bird species that the sponsoring organizations believe are in need of monitoring.

Several of these species have a high probability of exposure to granular carbofuran. Of the 26 species on this list, at least 15 species or closely related species (such as sandpipers, plovers, and sparrow groups) have been killed by granular carbofuran. These birds also include birds of prey such as red-shouldered hawks, northern harriers, and loggerhead shrikes. These birds warrant special attention because of their position in the food chain and because of the difficulties in monitoring secondary poisonings, which EPA believes is the mode of exposure for these birds. Hawks, in particular, warrant special attention because of their low reproduction potential.

Table II-13. Declining Species of Migratory Birds¹

Species	U.S. Fish and Wildlife Service Regions Where Status Is of Concern ²	Significant or Negative BBS Trend ³	Basis for Listing				Apparent Population Decline	Small Population Size	Restricted Habitat
			BBS or Other Data Indicating Decline	No BBS Data Available					
Common loon	5		x			x			
Reddish egret	2, 4		x				x		x
Least bittern	1, 3, 4, 5, 6			x		x			x
American bittern	3, 5					x			x
White-faced ibis	1, 6	x		x					x
Trumpeter swan	1, 6		x						x
Red-shouldered hawk	3, 5			x		x	x	x	x
Ferruginous hawk	1, 2			y		x	x		
Northern harrier	1, 2, 3, 5, 6					x		x	
Black rail	1, 2, 4, 6	x		x		x			x
Snowy plover	1, 2, 4, 6			x		x			x
Long-billed curlew	1, 6								x
Upland sandpiper	3, 5		x			x			x
Gull-billed tern	4, 5			x					x
Roseate tern	4, 5		x			x			x
Least tern	2, 3, 6			x		x			x
Black tern	3, 6	x				x			x
Barn owl	4, 5			x		x			x
Spotted owl	1, 2							x	
Loggerhead shrike	3, 5		x			x			x
Belt's vireo	1, 6		x			x			x
Golden-cheeked warbler	2								
Baird's sparrow	6		x						
Henslow's sparrow	3, 5		x			x			x
Bachman's sparrow	3, 4		y			x			x

¹ Threatened or endangered species are excluded.² The U.S. Fish and Wildlife Service Regions are as follows:

Region 1 - Portland, Oregon; Washington, Oregon, California, Nevada, Idaho, Alaska, Hawaii.

Region 2 - Albuquerque, NM; New Mexico, Arizona, Texas, Oklahoma.

Region 3 - Twin Cities, MN; Minnesota, Wisconsin, Michigan, Ohio, Indiana, Illinois.

Region 4 - Atlanta, GA; Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, South Carolina, North Carolina, Kentucky.

Region 5 - Boston, MA; Massachusetts, Connecticut, New Hampshire, Rhode Island, Vermont, Maine, New York, Pennsylvania, Maryland, Virginia, West Virginia, Delaware, New Jersey.

Region 6 - Denver, CO; Colorado, Utah, Kansas, Missouri, Iowa, Nebraska, Wyoming, Montana, North Dakota, South Dakota.

³ Narrative Breeding Bird Survey (BBS) trend at $p < 0.05$ in at least one of the regions listed.

While carbofuran is not considered the sole causative factor in the population declines of any of these birds, acute carbofuran-related losses may be an important additive factor in the decline of these species. Red-shouldered hawks, for example, are declining and listed as rare or endangered by several major corn-producing States. The population in Iowa was estimated to be 19 pairs in 1981 (Bednarz and Dinsmore 1981). Monitoring has already shown that secondary poisoning of this species has occurred. EPA considers carbofuran a potential risk to the remaining red-shouldered hawk population in Iowa, since carbofuran is used throughout the state. If only one or a few red-shouldered hawks were killed from carbofuran in Iowa, this amount would be an important additive factor in the decline of the species in that state.

EPA recognizes that many of the birds frequently found dead in the carbofuran field studies show BBS trends that are not declining or in some cases are actually increasing. EPA considered species such as crows, American robins, mallards, brown-headed cowbirds, and horned larks, have been found killed by granular carbofuran. EPA does not wish to diminish the importance of these species by not presenting BBS data on them. However, EPA determined that because of the declining status of many species of birds, it is important to focus attention on the species least able to cope with the acute mortality pressure because of their declining status. Crows, American robins, mallards, horned larks, brown-headed cowbirds, are among species that may be frequently encountered in the field studies because they are so abundant. Therefore, one would expect that these abundant species would be more frequently found than less abundant species. However, laboratory and field data indicate that once exposed to carbofuran, individuals of the less abundant species are likely to be equally susceptible to carbofuran intoxication as the more abundant species.

Furthermore, EPA also places importance on the observed rates of acute mortality in the "abundant" species. EPA considers the risk that carbofuran poses to these birds to be undesirable. While red-winged blackbirds, horned larks, American robins, and other such species presently may be abundant, EPA does not view losses attributable to pesticide use to be desirable. The abundance of certain species simply indicates that some of the species killed in the granular carbofuran field studies are more resilient, at least in the short term, than certain less abundant species.

EPA considers that an important aspect of carbofuran's risk to birds is that it is highly toxic to a wide variety of bird species, including many species that frequent corn fields. EPA is concerned that many of the species frequenting corn fields are also declining. The following sections outline some of factors supporting this concern.

EPA was limited by the quantity and quality of the BBS data available for a particular species. Therefore, the analysis is not all inclusive. EPA and the Patuxent Wildlife Research Center of the U.S. Fish and Wildlife Service jointly assessed the BBS data base in determining which species had BBS data that would be adequate for consideration in this review. Also, EPA considered birds that are known to use agricultural fields and whose BBS trends showed statistically significant declines in one or more BBS strata. EPA focused attention on these species because, considering that they are already showing statistically significant declines, it is prudent to expect that their populations may be more heavily influenced by pesticide-induced mortality than species that are not showing these declines. The results of this analysis are discussed below.

Red-shouldered hawk: The red-shouldered hawk is on state lists of declining or unstable populations of birds in Illinois, Michigan, Wisconsin, Alabama, Arkansas, Georgia, New Hampshire, New Jersey, Iowa, and Missouri (U.S. Fish and Wildlife Service 1982). This species has been on the Blue List (Tate 1981) for the past 10 years for most of its range throughout the country and may be recovering from recent population declines (U.S. Fish and Wildlife Service 1982). Loss of riparian woodlands is one possible factor in the decline of this species. Population indices show that both the decline and the recovery have been most dramatic in the South. Indices also suggest that this species has not been abundant in the northern and eastern States, which include the Corn Belt, at least in the last 30 years. A decline occurred in those areas prior to 1970.

BBS data from the mid-1960's through the mid-1980's (Appendix 3) show that a recovery of the red-shouldered hawk has occurred in the South, but not in the Corn Belt over the same period. Some Corn Belt gains in the early 1970's were not sustainable in the mid-1970's, while gains in the late 1970's were again lost beginning in 1980. While the availability of hawk habitat may be limiting the species in the Corn Belt, it is also the very area with the greatest potential for granular carbofuran exposure, and apparently the least able to sustain potential gains in red-shouldered hawk populations.

The risk of impacting this already depressed species in the Corn Belt is high because the breeding potential of the species is initially low and steadily decreases with each individual's death in this area. Each successive death has a proportionally larger effect on reproduction potential of the population, compared with the death of an individual bird of a prolific species such as red-winged blackbird, brown-headed cowbird, or mallard.

Northern Harrier: The northern harrier (marsh hawk) has been on the Blue List (Tate 1981) since 1971 because it has exhibited "potentially serious" declines (Evans 1982). These declines may be attributable to the draining of wetlands and plowing of grasslands, important habitats for this raptor. Also, nesting mortality may result from several factors. First, the ground-nesting habits of the northern harrier render eggs or young more likely to be preyed upon by mammalian predators such as skunks. Second, deer, cattle, and carrion beetles are also known to cause nesting mortality (Hamerstrom 1969). Third, farm practices such as haying are responsible for some nest destruction. Fourth, hunting and other interferences with reproductive behavior such as pesticide contamination are also considered contributing mortality factors (Evans 1982). While he did not consider pesticide contamination to be a "significant factor at this time," Evans (1982) suggested that "local populations may have been affected by agricultural pesticides."

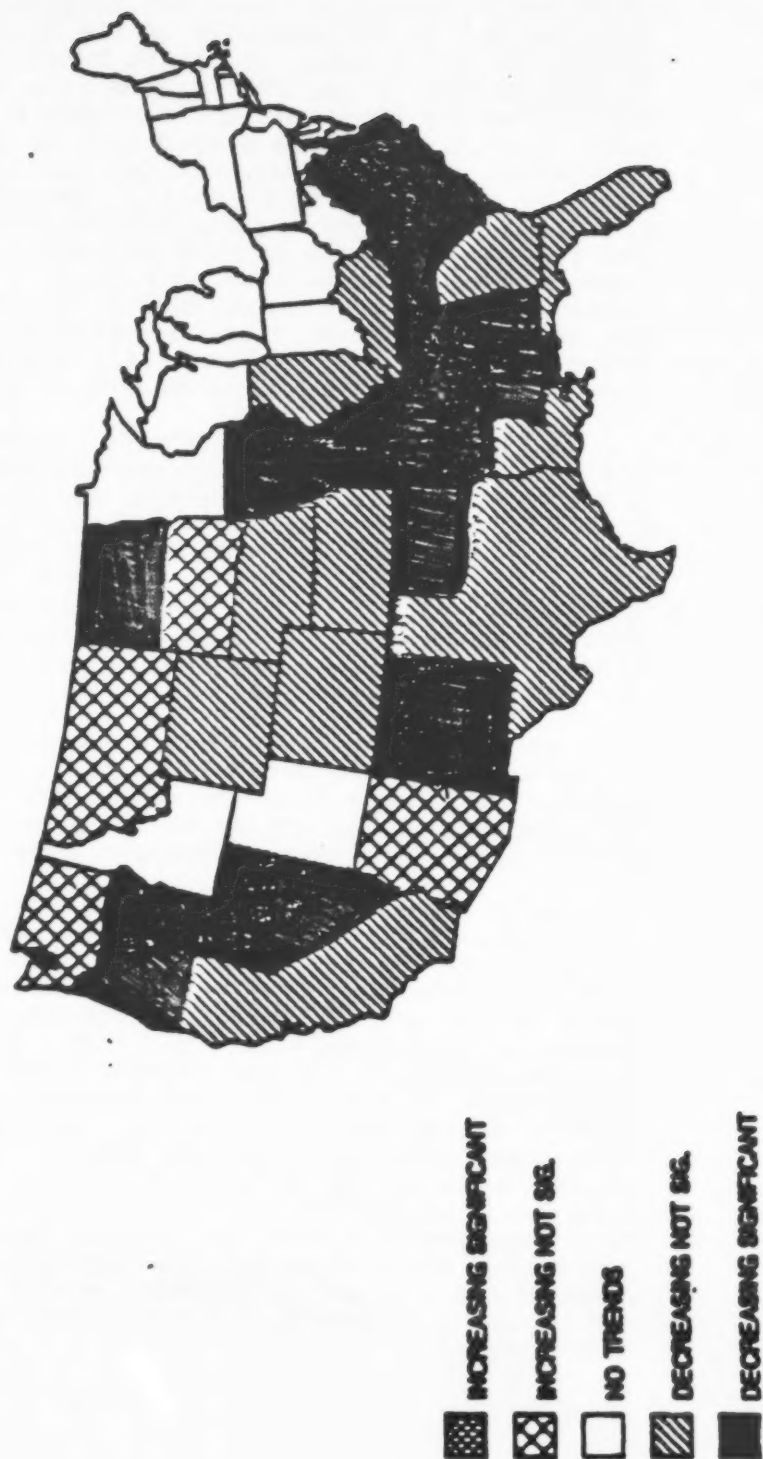
A 20-year BBS trend analysis (Appendix 4) for this species indicates that statistically significant ($p < 0.05$) declines have occurred in Minnesota, Colorado, Kansas, and Oklahoma. These States have substantial corn and sorghum acreage. Declines of northern harriers have also been recorded in Montana, Idaho, Nebraska, New Mexico, Texas, Illinois, and New York but were not significant at $p < 0.05$. Twenty-nine States exhibited no trends, which may not be interpreted as stable population trends. No trends can result from various causes such as insufficient data for statistical analysis.

Loggerhead shrike: The loggerhead shrike appears to have a higher reproduction potential than larger predatory birds such as hawks. Field data from the southeastern United States indicate that the loggerhead shrike may have been subjected to secondary poisonings by granular carbofuran (Overgaard et al. 1983).

Data for population trends of the loggerhead shrike (Figure II-2) extracted from 20 years of the BBS indicate the species is declining nationally. Widespread statistically significant ($p < 0.05$) declines have been measured for this species. Areas with the greatest concentration of this species (Appendix 5) also tended to have significant declines, while areas with lesser concentrations of shrikes tended to have declines that were not significant at $p < 0.05$. The statistical significance of the decline may be influenced by the larger sample sizes available in some areas. However, the observation did not hold true over the entire range of the shrike. For example, the Corn Belt states of Iowa and Missouri had significant ($p < 0.05$) declines, but have only moderate to sparse population densities of this bird. Population trend data for the southern states (Appendix 6), where shrikes are exposed to carbofuran uses on soybeans, corn, rice, and pine seed orchards, further illustrate the recent decline of this species.

Figure 11-2

LOGGERHEAD SHRIKE
BBS 20 YEAR TRENDS SIG ($P < 0.05$)



Anderson and Duzan (1978) reported that loggerhead shrike eggs had been contaminated with DDE in Southern Illinois, resulting in 2.57% thinner eggshells in 1971 and 1972. (DDE is an analog of DDT.) However, this study reported that despite this finding, "nesting success was high, suggesting that the factor, DDE or other, causing the recent decline of the shrike population of Illinois was more closely associated with survival of fledged juveniles or adults, than with reproduction." This acute mortality can be an important factor in the population dynamics of the loggerhead shrike. Robbins et al. (1986) suggested that shrike declines may be associated with roadside spraying and other factors, which include habitat loss or alteration.

Sparrows and Sparrow-like Birds: Robbins et al. (1986) cited BBS data for years 1965 through 1979 and found continental, regional, and local declines in many sparrow species. These birds are among the most sensitive to carbofuran with a single granule being lethal. Many of these species have been killed in field tests of granular carbofuran or have been reported poisoned as a result of the use of granular carbofuran. Some of these species have increased in certain states and others have declined. These increases and decreases are a result of the many factors that affect bird population dynamics.

BBS trend data for Henslow's sparrow through 1985 (Appendix 7) indicate a continuing population decline in their breeding range, the northern Corn Belt. Acute mortality from pesticide poisoning and loss of its preferred nesting habitat are of concern.

Song sparrows are frequently encountered in or near fields. The song sparrow had statistically significant ($p < 0.05$) declines in the Corn Belt States of Illinois, Indiana, and Ohio (Appendix 8). The neighboring states of Iowa and Pennsylvania had declines, but they were not statistically significant ($p < 0.05$). Texas, Colorado, and many Northern tier States had declines that were not significant ($p < 0.05$). Many States showed no trend.

Field sparrows may be encountered on the edges of woodlands. Although not likely to extensively use the interior of agricultural fields, they may use the edges of fields bordering on other habitats such as hedge rows. These birds have declined in the last 20 years (Appendix 9). The BBS data showed statistically significant declines ($p < 0.05$) throughout the north, central, northeastern, mid-Atlantic, and Corn Belt States. Midwestern sorghum-producing States such as Oklahoma and Kansas also showed statistically significant declines ($p < 0.05$). Texas, a major sorghum-producing state, measured declines that were not significant ($p < 0.05$). All eastern and midwestern States except Florida had declines, some of which were

significant ($p < 0.05$). Western states are beyond the range of the field sparrow and showed no trends.

Lark sparrows may be seen in meadows, fields, lawns, rock perches, and low bushes west of the Allegheny Mountains. They favor grasslands and sagebrush in the west, and are common in western states, where significant ($p < 0.05$) increases are being measured (Appendix 10). However, significant ($p < 0.05$) declines were observed in areas likely to have substantial carbofuran use such as Texas and Arkansas. A significant decline was also observed in Kentucky. Eastern and southeastern states with no trends are mainly in the migration routes for lark sparrows between the Gulf States and the Midwest. Lark sparrows are normally absent from the middle Atlantic States and the northeast.

The grasshopper sparrow, a species that has been killed in field studies of granular carbofuran, had significant declines in all parts of its range. Based on data through 1979, 12 States from the Dakotas to Maryland and West Virginia lost significant numbers of these birds (Robbins et al. 1986).

Based on data through 1979, vesper sparrows appear to be showing declines throughout its range. Agricultural practices, like more frequent cuttings of hay fields, are believed by some to have reduced nesting success in this species.

Two uncommon sparrow species of the northern plains showed significant declines based on data through 1979. Baird's sparrow and LeConte's sparrow, each with a small breeding population extending eastward to the Great Lakes (Robbins et al. 1986).

The rufous-sided towhee, while increasing in the west, decreased in the east, which gave a "slight but significant" continental decrease. The lark bunting declined "virtually throughout its range" (Robbins et al. 1986). Observations were made through 1979.

The American goldfinch is a bird that has been killed in field studies of granular carbofuran (U.S. Environmental Protection Agency 1987e). Small flocks are common in weedy fields, bushes, and roadsides. It has had significant ($p < 0.05$) declines in the northeast and in the Corn Belt states of Ohio and Iowa (Appendix 11). The Corn Belt states of Indiana, Illinois, Missouri, and the corn-producing State of Wisconsin have registered declines which were not significant ($p < 0.05$). Texas had no trend, while Oklahoma had a decline that was not significant ($p < 0.05$). Kansas, a sorghum producer, registered a significant ($p < 0.05$) decline, as did California and Oregon.

I. Comparative Avian Risk of the Alternatives

EPA compared the risk carbofuran poses to avian species to the risk posed by its alternatives. As stated previously (Section II.C), the greatest risk of granular products to avian wildlife may result from birds exposed to granules and ingesting them directly. In Section II.C, EPA compared the acute toxicity of carbofuran granules (in terms of the number of granules equal to an LD50 dose) to estimates of exposure (in terms of the number granules exposed and available to birds per unit area). This ratio can be used to compare the avian risk between granular carbofuran and its principal alternatives. Using this method of comparison, the Agency can identify the granular pesticides and uses that pose the greatest concern for risk to avian wildlife.

1. Toxicological Hazard

EPA assessed the acute hazard to birds from the principal alternatives to carbofuran by reviewing the laboratory acute toxicity data for each pesticide on a representative species of waterfowl (usually mallard), upland game bird (usually northern bobwhite), and songbird (usually red-winged blackbird). EPA used the lowest reported LD50 values in the literature (Smith 1987, Schafer et al. 1983, Schafer and Brunton 1979, Hudson et al. 1984, Hill and Camardese 1984, and Balcomb et al. 1984). The songbird value for terbufos was calculated from the data reported by Balcomb et al. (1984).

The principal alternatives are all acutely toxic to birds and are relatively quick acting. In addition, the granular formulations of these pesticides expose birds via ingestion to discrete doses of the pesticide. The manner of exposure (ingestion of granules) is comparable to that in LD50 toxicity testing. For these reasons, the LD50 value (milligrams of pesticide per kilogram of bird body weight which will kill 50% of the test population) is an appropriate toxicity parameter to assess avian hazard. The granular pesticides considered in this analysis are listed in Table II-14 in ascending order of their toxicity to birds based on their LD50 values (mg/kg).

As noted previously, birds will encounter these granular formulations as concentrated discrete doses, an exposure similar to the exposure in a laboratory acute LD50 test. To further assess the risk of these granules to birds, one must determine the number of granules that must be consumed to reach the acute LD50 estimated value. This can be calculated as follows:

$$\frac{\text{LD50 (mg/bird)}}{(\% \text{ AI}/100) \times \text{wt of 1 granule (mg)}} = \frac{\# \text{ granules}}{\text{LD50}}$$

The weight of a granule or a reasonable estimate of its weight for each formulation is crucial data. Results of the

Table II-14. Acute Oral Toxicity Values (LD50) of Carbofuran and Its Principal Alternatives Ranked by Ascending Order for Representative Bird Groups¹

<u>Chemical</u>	<u>LD50 (mg/kg)</u>
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Waterfowl

Carbofuran	0.238
Phorate	0.620
Aldicarb	3.400
Ethoprop	12.600
Trimethacarb	14.100
Terbufos	15.000
Fonofos	16.900
Chlorpyrifos	75.600

Upland Gamebird

Carbofuran	1.300
Aldicarb	2.000
Ethoprop	4.210
Phorate	7.000
Chlorpyrifos	8.410
Fonofos	12.000
Terbufos	15.000
Trimethacarb	67.200

Songbird

Carbofuran	0.400
Aldicarb	0.800
Phorate	1.000
Terbufos	2.100
Fonofos	5.200
Chlorpyrifos	5.620
Ethoprop	7.500
Trimethacarb	46.300

¹Source: Balcomb, et al. 1984; Shaefer and Brunton 1987; Smith 1987; and Agency files



above equation (i.e., the number of granules equalling an LD50 value), are very sensitive to changes in granule weight. There is variation in granule weight within and between granular formulations. Hill and Camardese (1984) and Balcomb et al. (1984) reported measured mean and median granule weights for a number of granular pesticides. These values were used as estimates of granule weights for these pesticides. Where no data were available for a particular pesticide formulation, EPA used the overall median value, 0.300 mg, as determined from the reported values in both publications.

2. Granular exposure

In Section II.B EPA established that birds will be present when granular pesticides are applied to the 10 use sites under analysis in this document. In Section II.C.3. EPA detailed how the risk to birds associated with the use of a granular pesticide can be quantified by examining the acute toxicity in the context of potential exposure, with exposure being measured on an area (e.g., square foot) basis. Based upon the equations and supporting literature in Section II.C.3., EPA calculated estimates of the number of granules/sq ft for carbofuran and its principal alternatives with granular formulations. EPA based these values on information from representative product labels, and examined the 10 use sites examined in this document.

3. Risk Assessment

Several types of information can be used to assess the risk that granular pesticides pose to birds. These include acute toxicity, number of granules that can kill a bird, field studies, and field kill incident reports. Appropriate data for assessing comparative risk posed to birds by the use of granular pesticides include toxicity and exposure. Section II.C.4 details how the measures of toxicity and exposure can be used to derive a relative measure of estimated risk to representative bird groups resulting from application of a granular pesticide. The equation is as follows:

$$\text{RISK} = \frac{\text{EXPOSURE}}{\text{TOXICITY}} = \frac{\text{GRANULES/SQ FT}}{\text{GRANULES/LD50}} = \frac{\text{LD50s}}{\text{SQ FT}}$$

Based on the toxicity and exposure estimates above, EPA estimated the number of avian LD50s/sq ft for carbofuran and each of its principal alternatives for each of the 10 use sites (see Appendix). The minimum and maximum LD50s/sq ft values were calculated for broadcast, band, in-furrow application and turn row areas. Table II-15 lists the highest values, excluding turn rows, for each pesticide by use site combination based on the use instructions stated on the label. In general, carbofuran poses a high risk to all the representative bird groups at most sites.

Table II-15 Comparative risk of carbofuran and its principal alternatives with granular formulations as measured by the estimated LD50s/sq ft for waterfowl, upland gamebirds, and songbirds. The values for each chemical by use site combination are the highest based on the use instructions stated on the label, excluding the estimates for turn rows.

Waterfowl

Chemical	Use Site									
	Corn	Cot-ton	Cran- berry	Pea- nuts	Pine- seed	Rice	Sor- ghum	Soy- bean	Sun- flower	To- bacco
Aldicarb		19		8				8		
Carbofuran	113	6	88	66	832	22	38	75	73	263
Chlorpyrifos	<1			<1			<1	<1	<1	<1
Ethoprop	5			5				1		10
Fonofos	3			3			<1			1
Phorate	17	27		26			14	34		
Terbufos	1						1			
Trimethacarb	1									

Upland Gamebird

Chemical	Use Site									
	Corn	Cot-ton	Cran- berry	Pea- nuts	Pine- seed	Rice	Sor- ghum	Soy- bean	Sun- flower	To- bacco
Aldicarb		178		78				78		
Carbofuran	115	6	89	67	847	22	38	76	74	267
Chlorpyrifos	14			7			10	10	6	21
Ethoprop	83			83				19		165
Fonofos	19			19			4			10
Phorate	8	13		13			7	17		
Terbufos	6						6			
Trimethacarb	1									

Songbird

Chemical	Use Site									
	Corn	Cot-ton	Cran- berry	Pea- nuts	Pine- seed	Rice	Sor- ghum	Soy- bean	Sun- flower	To- bacco
Aldicarb		1594		700				700		
Carbofuran	1355	70	1052	789	10002	261	443	902	880	3159
Chlorpyrifos	74			40			56	56	31	111
Ethoprop	167			167				38		334
Fonofos	160			160			32			80
Phorate	210	339		323			175	418		
Terbufos	166						166			
Trimethacarb	4									

J. Analysis of Rebuttal Comments

EPA received 12 public comments in response to the initiation of the Special Review of carbofuran. These comments as they pertain to the avian risk are analyzed below. Some of these comments also contained information regarding benefits. This information is discussed in Chapter III. The comments are listed in Appendix 12.

1. Comment: Washington State University (Comments #1 and #2) reported that carbofuran was the only insecticide registered for black vine weevil control in cranberries. The comment indicated that the use of carbofuran against this pest would not result in a hazard to birds because most of Washington's cranberries were not flooded, and waterfowl were not attracted to the bogs. Based on personal observation, the respondent indicated that he never sees birds walking in the bogs, possibly because the vines form a thick mat, which conceals the soil. The respondent also submitted a summary of a study (Lenhart 1980) of the potential effects of cranberry treatment to birds.

Response: EPA attempted to obtain a copy of the Lenhart study summarized in the comment. However, copies were not available; the author had retired and could not be located.

Part of the comment was testimonial in nature and cannot be factored into the Hazard Assessment in a quantitative way because the respondent's "observations" were unsystematic. Therefore, EPA cannot assess the accuracy of the respondent's observations.

It appears that the study itself was conducted systematically. However, very few details were included in the summary. Thus, EPA could not assess validity of the study, and could not incorporate the findings into a quantitative risk assessment. EPA assumes from the summary that no adverse effects were observed.

The author recommended the following restrictions on the use of carbofuran:

- (1) Treatment should be limited to "spot treatments" of nonflooded Washington cranberry bogs.
- (2) No application to "bare ground or to bogs where vines are less than two inches in depth."
- (3) Treatments be irrigated as soon as possible or within 24 hours.

EPA assumes that under other conditions wildlife losses could occur in cranberry bogs.

2. Comment: Abbott Laboratories (Comment #3)

that was available as an alternative to carbofuran for European corn borer control. The company indicated that they supported the Special Review of carbofuran, and that Dipel would be less hazardous to wildlife than carbofuran.

Response: EPA agrees that Bacillus thuringiensis is less hazardous to birds than carbofuran.

3. Comment: The National Audubon Society (NAS) (Comment #4) supported the granular carbofuran Special Review and was concerned about the potential effect on birds from direct and secondary poisonings. NAS proposed a hazard scenario similar to the one considered by EPA when the Special Review was initiated.

NAS was also concerned that carbofuran produces chronic biochemical and physiological effects that can potentially disrupt enzyme and lipid metabolism (Fisler 1985). NAS indicated that although these effects may be reversible, the implications of long-term exposure could be serious.

NAS also commented about the possible potentiation of cholinesterase inhibition by exposure to carbofuran and methyl mercury (Dieter and Ludke 1978). NAS indicated that EPA should require studies such as chronic toxicity tests to detect teratogenic, mutagenic, and carcinogenic effects of nitrosated carbofuran metabolites and other degradation products.

Response: EPA has little data on the effects of metabolites and degradation products on acute avian field hazards.

EPA could not quantify the extent of concurrent exposure of birds to both methyl mercury and carbofuran granules because data correlating the two were not available. However, EPA agrees with NAS that evidence is available concerning possible potentiation of cholinesterase inhibition by methyl mercury. The proposed mechanism for such potentiation could contribute to the death of endangered bald eagles through secondary poisoning because piscivorous species such as the bald eagle could contain elevated methyl mercury levels through exposure to contaminated fish.

EPA has received data on the chronic effect of the carbofuran active ingredient. James and Fox (1987) reported that the reproductive success of burrowing owls, a threatened species in Canada, was negatively affected by grasshopper control programs employing sprayable carbofuran. A progressive decline of the species in Canada has been described in recent years, but the causes remain to be determined. Although six insecticides were used in the study, only carbofuran and carbaryl areas had sufficient exposed burrows for statistical analysis.

The authors reported that carbaryl had "little effect" on productivity at both the 50 m and 400 m exposures. However,

exposure to carbofuran within 50 m of the nest burrow resulted in a 54% reduction in the number of young per nest ($p < 0.05$) and a 50% reduction in the proportion of pairs raising one or more young ($p < 0.05$) relative to a 50 m control. Because no pairs were exposed to carbofuran alone within 400 m, the results of exposures to carbaryl plus carbofuran at 400 m were compared to results of exposures to carbaryl alone at 400 m. The authors found that productivity of pairs exposed to both pesticides was 35% to 36% lower than those exposed to carbaryl alone ($p < 0.01$). The authors recommended that carbofuran not be sprayed within 400 m of active burrowing owl nests.

4. Comment: The Rice Research Board (Comments #5 and #13) indicated that light incorporation of the granules could reduce the hazard to birds.

Response: EPA has evaluated data indicating that incorporation of granules results in fewer granules exposed on the soil surface, but that birds are still killed. (See Chapter V.)

5. Comment: The Denver Audubon Society (DAS) (Comment #6) supported the Special Review of carbofuran but was concerned about the "uncertainties" in the data. DAS cited Field Study 1 (FMC Corporation 1983) as an underestimate of mortality because the search techniques were incomplete. DAS suggested that EPA's initial mortality estimates found in PD 1 were crude. DAS suggested that the mortality estimates would "undoubtedly increase" if EPA had estimated fatalities attributable to subacute or chronic toxicity of carbofuran. Finally, DAS expressed concern due to the potential for secondary poisonings of raptors.

Response: The mortality estimates made by EPA in the PD 1 were an indicator of the scope of the potential for environmental damage. The contribution of subacute or chronic toxicity to the total mortality could not be quantified by the data available. EPA addresses secondary poisoning within Chapter II of this document.

EPA is also concerned about the impact of carbofuran on populations of birds. EPA addressed those species in which acute mortality may have an undesirable effect because of small population size in Section F of this chapter.

6. Comment: The U.S. Forest Service (Comment #8) commented on the efficacy of granular carbofuran for seed and cone insect control in pine seed orchards and on the economic value of pine seed and pine trees. The Forest Service also claimed that the use of the modified POWR-TILL Seeder (Overgaard et al. 1983) decreases the potential exposure of granules and hence hazard to birds.

The U.S. Forest Service also submitted the results from several models showing a potential for aquatic contamination resulting from the pine seed orchard use of granular carbofuran. The U.S. Forest Service claims that aquatic impacts can be eliminated by the construction of catchponds designed to trap runoff water and filter it through a 30-inch soil bed on top of drain tiles to remove residues.

Response: EPA agrees that it appears as if substantial reductions in the numbers of granules available to birds could be achieved through the use of a modified POWR-TILL Seeder in pine seed orchards. However, granules still remained unincorporated on the soil surface, and birds died from carbofuran exposure.

The potential aquatic risks of granular carbofuran are not the basis for this Special Review. The hazard to aquatic animals is being evaluated through the reregistration process.

7. Comment: D. Heminway (Comment #9) submitted a variety of information concerning the avian hazard from carbofuran. The information was related to a topics including pharmacology, chemistry, and a bird kill in New York State bird kill.

Response: EPA incorporated the information into this document as appropriate.

8. Comment: New York State Department of Environmental Conservation (NYSDEC) (Comment #10) submitted gas chromatography/mass spectrometry data on soil surface exposure of carbofuran granules from a corn field bird kill in 1979. NYSDEC also included residue analyses data concerning a carbofuran-poisoned red-tailed hawk. Information concerning other bird kill incidents reported after granular carbofuran use in corn and soybeans was also submitted.

Response: New York's data regarding the poisoned red-tailed hawk were included in the discussion of secondary poisoning incidents from carbofuran.

Some of the 1983 waterfowl kill information from New York corn fields does implicate granular carbofuran as a cause of death of wood ducks. However, some of the data on other species are not definitive because the corn seed used to plant some of the fields may have been coated with diazinon. EPA agrees that both pesticides were present at sufficient levels to kill these birds. These data were not included in EPA's assessment of bird kills from direct carbofuran poisoning.

EPA agrees that the American robins killed in the 1979 incident in a corn field treated at-planting with granular

carbofuran died from carbofuran. This bird kill incident was included in Table II-8, which summarized the bird kill incidents from direct carbofuran poisoning.

9. Comment: The University of California (Comment #11) expressed concern for retaining carbofuran use for rice water weevil control because no other alternatives are registered.

The University also commented on the waterfowl kills in which the Cooperative Extension Service indicated that "Five incidents of duck losses were determined to involve carbofuran in 1985, involving a total of 30 ducks." Laboratory reports from the California Department of Fish and Game were submitted showing high levels of carbofuran in the dead birds.

The respondent indicated that waterfowl surveys in the rice-growing area of California ranged from 72,000 to 172,000 ducks. The respondent felt that "the loss of 30 ducks would not seem significant."

The respondent suggested that although the bird losses are insignificant, that the California Department of Fish and Game, the California Department of Food and Agriculture, and FMC Corporation agreed to recommend two procedures for rice growers using granular carbofuran. The first is to require a preplant-incorporated treatment in the first two fields to be flooded if carbofuran is to be used within 1 mile of any wildlife refuge. The second is to allow postplant treatment of drained fields, followed by reflooding. An information leaflet would go out to all rice growers making them aware of the potential waterfowl hazard.

Response: The detailed waterfowl kill information from the California Department of Fish and Game reveals waterfowl kills in 1984, 1985, and 1986. These kills were not limited to waterfowl. A northern harrier and red-tailed hawk were also killed in rice fields, indicating possible secondary poisoning.

EPA does not agree that the proposed restrictions can mitigate the hazards to nontarget species resulting from use of granular carbofuran on rice because no systematic field study data are available that would enable EPA to draw this conclusion.

Comment: FMC Corporation (Comment #7) submitted comments concerning the Carbofuran Special Review. The major points covered by FMC are summarized below, as well as EPA's response.

1. Comment: Carbofuran did not exceed the risk criteria for Special Review existing at the time (40 CFR 162.11(a)(3)(i)(B)(2)) because the criteria can only be applied to foliar applications that leave a predictable toxic residue in or on bird food items. FMC further stated that the criteria were

not exceeded because crops were not present during carbofuran at-planting application and therefore no immediate residues could occur on avian feed. Thus carbofuran would not result in the general contamination of bird food.

Response: In the PD 1, EPA referred to the regulation concerning the risk criteria as being " . . . literally applied only to foliar applications that leave predictable toxic residues in or on avian foods." This reference reflects a practice of EPA wildlife biologists of applying estimated residues based on application rates to predict zero-hour residues on various vegetative substrates including avian food items. These residues may be compared to laboratory-derived LC50 values from tests of technical-grade active ingredient. The comparison of predictable foliar residues with the LC50 is "the literal application of the regulation"

EPA determined that the Special Review was properly initiated and that the risk criteria do not refer to "predictable foliar residues." The risk criteria indicate that a Special Review may be appropriate if a pesticide "occurs as a residue . . ." on avian feed items, which occurs with carbofuran. Bird kills have occurred in fields where contaminated earthworms and small birds were observed. Lethal carbofuran residues were measured in these avian feed items. Dead American robins, which could have ingested contaminated earthworms, and dead red-shouldered hawks, which could have ingested contaminated birds, were also found to have lethal carbofuran residues. The examination of the earthworms indicated carbofuran residues were present at levels exceeding avian LC50 values.

FMC also indicated that avian feed items cannot be contaminated because carbofuran is applied at-planting. This implies that birds only feed on crop material. However, birds may be found in bare, newly planted fields probing the soil for grit, seeds, or invertebrates. Also, certain label directions allow the use of carbofuran on a maturing corn crop, which would be an unincorporated use directly contaminating avian feed items.

Although carbofuran application may not result in the "general contamination" of most bird foods, application results in the contamination of avian food items. These food items plus the ingestion of the granules themselves as grit, a necessary component of some species' diets, result in birds ingesting carbofuran residues exceeding threshold levels indicated in the risk criteria.

2. Comment: Carbofuran did not exceed the second risk criterion for Special Review (40 CFR 162.11(a)(3)(ii)(c)), which indicates that a pesticide use may result in a significant local, regional, or national population reduction.

Further, FMC indicated that "risk assessment implies the need to assess population effects." FMC provided a discussion of avian population dynamics and contends that "the significance of the avian mortality cited in PD 1 must be assessed in light of information on naturally occurring bird mortality, the incredible reproductive potential of birds and typical baseline trends in bird populations." FMC submitted information on reproductive potential and indicated that bird populations have remained and are stable because of this potential, despite avian mortality from diseases, manmade structures, predation, weather, climate, and other sources. FMC claims that pesticide-induced avian mortality must be considered along with these other sources of mortality, which FMC claims so far have not affected bird populations. FMC also indicated that no bird population declines have occurred in species that are commonly found in areas of carbofuran use.

Response: EPA agrees that information relating to naturally occurring bird mortalities, reproduction potential, and baseline trends are essential to an understanding of avian population models and dynamics.

EPA concurs that many populations of birds, including red-winged blackbirds, common grackles, brown-headed cowbirds, horned larks, mourning doves, and American robins are stable. Most of these species are very likely to be exposed to agricultural uses of granular carbofuran. EPA agrees that many of these species can reproduce quite prolifically.

However, other populations of species are declining in number, and FMC did not provide an analysis of the status and breeding potential of these declining species. Some of these species are found in areas treated with carbofuran (Section H of this chapter). Although EPA does not attribute the decline of these species to carbofuran alone, EPA is concerned about the important effect of carbofuran-induced mortality on these populations. Some of these species do not have a high reproduction potential.

EPA found that the information FMC presented on reproductive potential was deficient. The data were limited in scope and listed only percentages of eggs hatched and young fledged. Information was not provided on the actual potential for production of young, such as clutch sizes or existence of multiple clutches.

Although this information was presented incidental to a discussion of the effects of predation on reproduction, the data did not specifically address predation. Although some egg loss to predation is to be expected, a number of other factors are also responsible for the ultimate numbers derived from the almost 50 studies summarized by FMC.

EPA agrees that food supply, predation, habitat quality, and weather can all have effects on bird population dynamics. However, EPA disagreed that these factors diminishes the presumption of hazard in this case. These are dynamic factors acting on bird species at various times to one degree or another. Their presence and effects, while difficult to measure directly in pesticide field studies, are accounted for in the control or baseline portions of these studies.

Regarding the FMC comments relative to mortality of birds due to collisions with man made structures, EPA found the data referenced in the submission do not substantiate the numbers claimed. The estimates of mortality are very speculative and based generally on uncontrolled or casual observations at a few sites. Klem (1978), the only controlled study, indicated that his estimates are "fundamentally speculative" and that "evidence supporting (his) assumptions is not available." Their impact to particular species and their ecological consequences were not discussed by FMC.

Finally EPA did not suggest in the PD 1 that carbofuran-related mortality was "having a significant additive effect to losses . . ." of blackbirds, robins, larks, wrens, sparrows, and crows over and above those losses related to food supply, weather/climate, predation, etc. The PD 1 referred to "significant additive" mortality related to carbofuran poisoning of hawks and other birds of prey.

3. Comment: FMC indicated that EPA required FMC to conduct a study (FMC Corporation 1983) to represent a "worst case" scenario. As a result, FMC claims that this study was an atypical study of avian field hazard because carbofuran was applied at 4 lb ai/A. This is not a typical rate of carbofuran application.

In addition, FMC contends that the observed field mortality is not biologically significant and that extrapolation of data from field studies is not appropriate.

Response: EPA required the study to support the registration of carbofuran, which allows the application of 4 lb ai/A based on a 30-inch row space.

EPA agrees that even in the incorporated treatments, higher application rates will result in more granules above and below soil surfaces. However, rate reduction may not "significantly lower levels of bird mortality." (See Chapter V.D.)

FMC commented that birds in the field study had a higher probability of picking up granules because the study used 4 lb

ai/A instead of 1 lb ai/A. FMC stated that it assumed that "birds picking up granules was purely a random process."

EPA finds no evidence or rationale to support this assumption and has some evidence (U.S. Environmental Protection Agency 1980) that some birds do not pick up the granules randomly. In fact, FMC (1983) suggested that this is a nonrandom process. Also, the probability of a bird picking up and dying from 10G and 15G is approximately the same (Chapter V.D.4.)

FMC stated that lower levels of mortality were observed in "the other corn field avian monitoring studies where Furadan granules were applied at more conventional rates of 1.0 lb ai/A."

EPA agrees. However, if the effect of the unusual concentration of the horned larks in the Utah study is excluded in estimating the number of birds killed per acre, the rate is comparable to the lower mortality rate of the other field studies.

FMC commented that two specific cultural practices contributed to the significant bird mortality observed in the FMC study. First, FMC cited the 2-week postponement of the "normal" irrigation practice followed by a cultivation. Second, FMC cited the test protocol reviewed by EPA as requiring that spilled or unincorporated granules remain uncovered.

EPA was unable to verify that a "normal" or standard irrigation/cultivation date exists in that state. Throughout the majority of the Corn Belt, corn is not normally irrigated. In Utah, planting begins around April 28 and is about one-half completed by mid-May. By May 22 about 80% is planted, and 50% has emerged. In the area of the field study about 5000 acres of corn are planted and all are irrigated. Irrigation and cultivation timing depend on previous rainfall, with cultivation generally occurring approximately 1 to 1.5 months after planting (Lewis 1986).

The observed peak of avian mortality in the FMC study occurred about day 30 to 35 postplant, about the time of cultivation. However, mortality continued until at least 60 days postplanting after cultivation had occurred. Mortality occurred prior to cultivation as well.

Also, EPA did not require that spilled granules be left exposed on the soil. EPA's record of the protocol consultation suggests only that "large concentrations of granules" exposed as a result of "normal agricultural practice" would not be expected to be covered up. Nonincorporation of exposed granules on row ends is considered typical and covering the exposed granules on row ends by a farmer "moving the soil with his foot" is not

normal agricultural practice. Field investigators routinely report that common practice is to plant without regard to covering spilled or unincorporated granules (Stone 1979, Stone and Gradoni 1986, Balcomb 1986, Jaber 1986, Patterson 1986a).

4. Comment: FMC commented that the 831 dead horned larks found in Field Study 1 did not represent a typical avian hazard. FMC also commented that the cropstand in the FMC study was relatively poor, leaving open areas that would be particularly attractive to horned larks.

Response: Since much of the mortality occurred prior to the emergence of the crop, the data presented for crop stand are not particularly useful to the analysis. EPA agrees that the abundance and behavioral habits of horned larks are two important factors in interpreting the body count of 831. EPA also agrees mortalities associated with flocking birds should not be used in comparing mortality rates among field studies. However, one should not totally discount flocking-related mortality as non-representative of avian behavior. Several species of birds that frequent carbofuran use sites do exhibit flocking behavior.

EPA is concerned about this study because it also resulted in non-horned lark mortality as well. Predators and scavengers appeared to be attracted to the site by the considerable mortality among small birds. This scavenging and predation led to secondary poisoning. Notwithstanding this, EPA has not considered the effect of the horned larks when comparing the rate of mortality of this field study to the others.

5. Comment: FMC contended that the field study (Field Study 2) by Balcomb et al. (1984a) did not show biologically significant mortality and should not be used to assess avian hazard because no pretreatment observation establishing baseline data for comparison of bird mortality before and after treatments was made. Many specific criticisms cited data from the BBS, weather-related avian mortality, and an objection to "speculation" about the extent of the bird kill. Also, FMC pointed out that no raptors were found dead during this study.

Response: EPA agrees that baseline data are important to good experimental design if pre- and posttreatments are compared. Since this study's objective was explicit (i.e., measuring avian carbofuran residue accompanying at-planting applications), the authors did not attempt to statistically manipulate pre- and postapplication information, thereby diminishing the importance of baseline data on bird mortality for validation of these results. EPA does not agree that this study is invalid because of those reasons stated previously in the evaluation of this study.

EPA considers this study to be an indicator of the potential of granular carbofuran to acutely poison small animals when carbofuran is applied to corn at-planting and at low application rates. Although a specific sampling plan for residue analysis was not given, EPA considers the cause of death of the birds found in treated fields to be acute carbofuran poisoning because high residues of carbofuran were detected in these birds. EPA agrees that secondary poisoning of raptors was not observed in this study.

6. Comment: FMC criticized EPA for "simply highlighting bird mortality numbers and not pointing out other facts from the study by Overgaard et al. (1983)" (Field Study 4).

Response: EPA highlighted the mortality in this study (Field Study 4) because the acute poisoning potential of the incorporated granules was the most pertinent information to this Special Review. Other aspects of the study were not as important to the Special Review because this study is specifically of the POWR-Till Seeder, which is not now used to apply carbofuran for the major grain uses.

7. Comment: FMC commented that EPA "incorrectly" used the bird mortality information in this study (Overgaard et al. 1983) to conclude that carbofuran's use resulted in extensive bird mortality. To support this view FMC quoted the authors as indicating that "caution is needed when making judgments based on body count."

Response: The POWR-Till Seeder achieved a very high degree of granular incorporation and resulted in more granules being incorporated than with conventional farm application equipment.

Regarding the quotation on body counts, it appears that this was taken out of context and that the authors' intentions were opposite of what FMC has implied. EPA believes the authors intended to caution readers about underestimating mortality based on body counts and not overestimating, as FMC implies. The complete quotation is:

"However, caution is needed when making judgements based on body count. Pretreatment population surveys and a knowledge of the feeding habits of the involved species are valuable data to have when planning treatments. Additional data is needed to define the extent of mortality that occurred outside the search areas or over a longer post-treatment period, and the extent of the loss of dead or moribund birds through predator or scavenger activity. A thorough assessment of all such data is necessary to adequately understand the effects of carbofuran treatment on local bird populations (Overgaard et al. 1983)."

When these suggested measures are taken in avian field studies, the mortality estimates substantially increase above the number of carcasses observed in the study.

8. Comment: FMC argues that it is difficult to assess the potential hazard of Furadan 3G application to rice fields because the experimental design and manner in which data (Flickenger et al. 1980) are presented and that these data are not amenable to a thorough analysis. The authors did not present comparative data between carbofuran-treated and control areas and did not present their observations as a function of time before and after treatment.

Response: EPA generally agrees with this comment and therefore did not include this study in this hazard assessment.

9. Comment: FMC claimed that EPA ignored the study by Kleinert (1974) on the potential avian hazard of pesticide granules to birds in its PD 1. They state that this is a multiyear, multisite study and that the evidence suggests that the mortality is insignificant.

Response: EPA received this study in response to the PD 1 after the close of the public comment period. Thus, it was not included in the PD 1. EPA has now reviewed this study and finds it inadequate. This paper contains little information on application rates and only minimal information on methodology. The field investigations generally occurred 24 and 48 hours after applications, with a few samples at 144 and 192 hours after application. The experimental design and the general protocol are inadequate for a carcass search study. No investigation was made of the impact of predators and/or scavengers.

10. Comment: FMC questioned the discussion of the results of the Balcomb (1983) study (Field Study 3) and claimed that no "population impact of any chemical on raptors, other than of organochlorines, mercury and thallium sulfate and organophosphates" have been published. They referred to "The Christmas Bird Count" and several other sources to support their contention that carbofuran has not caused population declines in raptorial birds.

Response: The comments were critical of the broad interpretation of the results and not of the results themselves. EPA assumes that FMC therefore agrees with the author's conclusions that acute carbofuran poisoning was the cause of death of the red-shouldered hawk in this study.

FMC listed major pesticide chemical classes in discussing important raptors but did not include carbamates. Field data indicate that granular carbofuran, a carbamate, may result in

secondary poisoning of predatory birds, as previously discussed in this chapter.

The citation of pre-1970 hawk population declines noted in such surveys as the BBS or Audubon Field Notes (Christmas Bird Counts) also is insufficient to rebut the contemporary observations of secondary poisoning of raptors by granular carbofuran. EPA maintains that contemporary threats to already declining species should be carefully monitored, but for reasons discussed in the Hazard Assessment, this may be difficult to do with raptorial species.

The BBS is critiqued in a separate comment below. The Christmas Bird Count is performed on 1 or 2 days in December of each year, and is an inadequate indicator of raptor population estimates for EPA's purpose in the Hazard Assessment. Fuller and Mosher (1981) suggest that this count can function as an "index of the abundance of some species." Because of the methodologies, however, none of these surveys can assign (or discount) specific causes to the observations. Thus, there is no evidence to support FMC's contention that information from these counts "makes it evident that causes other than carbofuran are leading to population declines of the red-shouldered hawks." The surveys present no data or evidence of cause and effect.

FMC specifically responded to previous EPA concerns for the red-shouldered hawk. FMC claims that population declines in this species were noted long before the initial use of carbofuran in 1970. EPA agrees. FMC cited the U.S. Fish and Wildlife Service (1982) to support their contention that the cause of a decline in this species is loss of riparian woodland. This document specifically states that "little information on the causes of population declines was forthcoming in the listing process." It implicates habitat destruction as a cause of red-shouldered hawk decline specifically only in the East. Finally, this document says that the hawk is "thought" to be recovering, that the cause of the decline is "unknown," but that loss of riparian woodland is "one possibility." While it is likely that habitat destruction contributes to the decline in this species, EPA cannot discount the known secondary hazards to this species, especially now that populations of red-shouldered hawks are low.

11. Comment: FMC suggested that EPA has overreacted to the "few" carbofuran-related mortality incidents and indicated that these deaths are not biologically significant, as evidenced by data in the BBS, and that the use history of carbofuran shows no indication of large bird kills.

FMC also stated, "If the level of avian mortality observed in the Utah study was a normal occurrence, it most certainly would have come to the attention of local, State, and EPA officials, and most certainly would have been publicized in the

press." They further stated that "it is inconceivable that incidents of this magnitude would have gone unnoticed. . . . survey information currently available clearly demonstrates that populations of species commonly observed in and near corn fields (e.g., blackbirds, robins, lark spp.) have not declined (Robbins et al., 1985)."

Response: EPA has documentation of over 40 bird kills (Tables II-8, II-9, and II-10) for which the cause of death is either confirmed as lethal concentrations of carbofuran or for which carbofuran is strongly implicated. EPA did not use anecdotal reports or incidents of established misuse.

EPA determined that these kills underestimate the number of kills that have actually occurred because of the problems associated with reporting of bird kills. (See Sections F and G of this chapter.)

In the hazard assessment, EPA discusses survey information currently available, which shows that populations of bird species utilizing corn fields are declining with statistical significance.

12. Comment: FMC's analysis of the avian hazards and of population levels rely heavily on BBS. FMC suggested that the data in this multiyear survey proved that carbofuran is having no effect on those bird populations susceptible to poisoning by it, and further that the BBS shows that most if not all major decreases in bird numbers are either weather related or result from habitat destruction. FMC also commented that bird collisions with tall buildings and other man made structures should be considered a major factor in population effects.

Response: EPA does not agree that the BBS information currently available "clearly demonstrates that populations of species commonly observed in and near corn fields . . . have not declined." The hazard assessment provides further discussion.

Robbins (1985) indicated that generally the BBS could not reliably detect changes in bird populations until at least 10% of the population was affected. Furthermore, birds must have certain habits and habitats that would allow them to be detected in a survey such as the BBS, which is conducted by automobile survey routes. For example, raptors would not be readily found because their habitat is frequently not easily accessible, especially by car. BBS data present no data on "cause and effect."

13. Comment: FMC commented that laboratory and field data indicate that carbofuran is not chronically toxic. FMC asserted that "acute toxicity (mortality) plays only a minor role in population dynamics of a species. Declines in animal populations

do not occur from acute toxicity unless widespread massive mortalities of a species occur globally."

Response: EPA agrees that very little is known of the chronic and sublethal effects of carbofuran on birds because definitive data on granular formulations are not available. However, new data on flowable carbofuran's effect on owl productivity have been discussed.

However, EPA has not concluded that acute mortality plays only a minor role in population dynamics. For example, much of the basis for game management of birds and other animals are the "bag limits," a measure of acute mortality that are derived from existing population levels and accepted management strategies. EPA does not agree that animal population declines only occur through "global" mortality because populations of declining species frequently are not globally distributed and, indeed, may be quite localized.

EPA notes that acute mortality can become an important component in the acceleration of the decline of endangered, threatened, or declining species. The lower the existing population level, the more important each bird loss becomes to the reproduction potential of the population. This is especially true if the species has low reproduction potential. Since many populations of wild animals today exist at low levels, EPA cannot ignore the impact of acute mortality on populations.

14. **Comment:** With the exception of isofenphos and trimethacarb, FMC stated that the alternatives are toxic to small birds, with 10 or fewer granules being a lethal dose for red-winged blackbirds or house sparrows. FMC further stated that of the alternative chemicals suggested by EPA all are acutely toxic. FMC contended that organophosphate pesticides "may pose a greater secondary hazard to raptors than the carbamates since they irreversibly inhibit acetylcholinesterase, are more slowly metabolized, have greater half-lives and generally have more toxic metabolites than carbamates."

Response: EPA agrees that certain of these alternative chemicals are also acutely toxic to small birds in laboratory studies. However, EPA's analysis of the alternatives is based on a comparison of acute hazard and exposure to three representative types of birds. For further information, refer to Section I of this chapter, which presents the risk assessment for carbofuran and its alternatives.

15. **Comment:** FMC contends that "blackbirds are more acutely sensitive to chemicals than other wild and domestic avian species."

Response: EPA does not generally agree with this comment. To support their contention, FMC referenced a study by Schafer published in 1972. The study tested only starlings and red-winged blackbirds. Schafer and Brunton (1979) stated that only "Passeriformes may be significantly more sensitive to chemical intoxication than some Galliformes." EPA does not find support for FMC's statement about the greater sensitivity of blackbirds over other avian species.

In the text of their comments FMC cites "Eastin et al. 1982, Gure 1982, Rattner et al. 1982, and White et al. 1983" as substantiating their contentions regarding the severity of organophosphate hazards, yet these studies were not identified in their bibliography. Since EPA could not identify these data, their validity and/or the applicability of these studies to this Special Review could not be determined.

K. Conclusions

In this Technical Support Document, EPA evaluated the risk to birds based on acute avian toxicity, exposure, an estimated index of risk, field studies, bird kill incidents, population effects, and the toxicity and estimated risk of the alternatives pesticides.

Based on laboratory data, EPA concluded that carbofuran is acutely toxic to birds, and that a single granule may kill a small bird. Birds, including endangered species, are expected to be present at the time of carbofuran application to all use sites. Dietary exposure occurs from direct ingestion of granules and exposure from ingestion of contaminated soil invertebrates such as earthworms. Predatory birds also may be secondarily exposed to carbofuran by feeding on vertebrates such as small birds. Residues in wildlife confirm that such exposure to carbofuran has occurred.

Six field studies conducted at 11 locations investigated the loss of birds from label-directed, soil-incorporated uses of 10G and 15G applied as band and in-furrow application and 10G using specialized equipment. All studies consistently resulted in bird mortality, regardless of application rate and when applied using commonly practiced techniques for soil incorporation of granules. Both direct and secondary poisoning occurred. The rates of mortality varied from 0.1 to 3.6 birds per acre. EPA concludes that bird mortality following the label-directed use of granular carbofuran is a frequent and regular occurrence. Furthermore, the magnitude of the acute mortalities could be more heavily influenced by the numbers of birds entering treated fields, rather than by the extent of incorporation of granules or application rate.

Bird kill incidents from direct carbofuran poisoning have occurred in several crops in various areas of the United States and Canada. The types of birds varied and included both migratory and nonmigratory birds. Bird mortality was frequently associated with at-planting application but has occurred with other uses at other times of the year. Direct poisoning of birds has caused over 40 reported bird kills.

Secondary poisoning incidents have also occurred and involved bald eagles, red-tailed hawks, red-shouldered hawks, northern harriers, and others. Such species are attracted to dead and dying smaller birds and small mammals affected by granular carbofuran.

Secondary poisoning of birds usually most affects those species that produce only a few young per year and are slow to reach sexual maturity. Thus, the death of each individual of these species can have important consequences for a population. A computer model of a small breeding population of bald eagles that had experienced several secondary mortalities due to granular carbofuran was used to illustrate this point. If the rate of carbofuran-related mortality observed in this population remains constant, the model predicted that the small breeding population will remain static over a 10-year span, even under ideal breeding conditions. At secondary mortality rates slightly higher than those observed in this population, the model predicted that the breeding numbers could decrease over the short span of the model.

The direct and secondary bird kill incidents that have been reported underestimate the number of incidents actually taking place because of the problems associated with the reporting of bird kills and with carcass removal by predators.

Populations of declining or endangered species may be present in areas where carbofuran is applied. EPA cited documented population declines of the red-shouldered hawk, loggerhead shrike, and predatory birds. Other declining species such as the field sparrow and Henslow's sparrow, which may be killed directly by feeding on a single granule, are exposed to granular carbofuran in areas where it is heavily used. Statistically significant declines have been measured for several species.

EPA does not consider granular carbofuran to be the sole causative factor in the decline of the bird species discussed. However, carbofuran is one of the most highly toxic pesticides to which these birds are exposed. Given its widespread use in agriculture, carbofuran is likely to be responsible for bird deaths in these species. EPA concluded that granular carbofuran can, therefore, be an important additive factor in the declines. The granular formulations make it even more likely that birds of

more likely that birds of these species will be killed, because these birds can frequently encounter granules during their feeding activities, or in the case of raptors and other birds of prey, are killed through secondary poisoning.

In the Biological Opinion for carbofuran, DESHC indicated that the Aplomado falcon, Attwater's greater prairie-chicken, and Aleutian Canada goose were the bird species jeopardized by the use of carbofuran. To avoid jeopardy to these species, OES indicated that the use of carbofuran should be eliminated in certain areas. DESHC also indicated that the bald eagle, whooping crane, and Mississippi sandhill crane may be adversely affected. DESHC recommended prohibiting the use of carbofuran in certain areas.

Generally, in comparison with the alternatives, carbofuran appears to pose the greatest risk to avian species based on estimates of the numbers of LD₅₀s/sq ft. The available field data support this conclusion.

III. BENEFITS ANALYSIS

A. Introduction

The Agency's benefit analysis was directed primarily towards the following use sites: field corn, sorghum, soybeans, rice, peanuts, tobacco, cotton, cranberries, pine seed orchards, and sunflowers. Registrant and user comments are solicited on all aspects of this analysis regarding the use of granular carbofuran. The common and scientific names for the insects and nematodes discussed in this chapter are listed in Appendix 13.

Carbofuran is a carbamate insecticide and nematicide that is generally applied when seeds are planted at the beginning of the growing season. Application is made to control pest problems that may or may not occur later in the growing season. Carbofuran may also be applied later in the season in certain cases. Field corn is the crop that accounts for most carbofuran use; use in the other crops is minor in comparison. A detailed summary of usage is provided in Table III-1.

Approximately 7 to 10 million lb ai of all carbofuran formulations are used annually in the United States. The Agency estimated that the granular formulation accounts for 85 percent of the total volume of carbofuran applied each year, while the flowable formulation accounts for the remaining 15 percent of the market.

Approximately 6 to 9 million lb ai of granular carbofuran may be applied annually to a variety of agricultural crops and forestry sites. The 10 sites specifically assessed by the Special Review encompass over 95 percent of the granular uses of carbofuran, or 85 percent of all carbofuran usage including use of both the granular and flowable formulations.

In its assessment of economic benefits, the Agency attempted to distinguish between the granular and flowable use of carbofuran. For some sites such as rice, peanuts, pine seed orchards, and cranberries, only the granular formulation is registered for use. For other sites, such as alfalfa and the small grains, only the flowable formulation is registered for use. For these sites, any reported usage can be attributed solely to either formulation.

For other sites, it is not easy to distinguish between the use of granular and flowable carbofuran because both formulations are registered for use on the same crops. Usage surveys do not always indicate which formulation is being applied for pest control. In some instances, the timing of application may be used to determine which formulation growers are applying.

Table III-1

Estimated U.S. Usage of Carbofuran by Registered Site and Formulation; Current Typical Year Estimates

Site	Registration ¹ Formulations	Extent of Usage Flowable		Extent of Usage Granular		Extent of Usage Total	
		1000 lb ai	% of G ai	000 lb ai	% of G ai	000 lb ai	% of Total
Corn (field)	F/G	-	-	4500-5500	68.0	4500-5500	58.0
Rice	G	-	-	160	2.2	160	1.9
Tobacco	F/G	300-400	27.8	100-200	2.0	400-600	5.8
Peanuts	G	-	-	218-573	5.4	218-573	4.6
Soybeans	F/G	-	-	265.3-485	5.1	265.3-485	4.4
Sorghum	F/G	-	-	480-1500	13.5	480-1500	11.5
Cotton	F/G	-	-	30	< 1	30	< 1
Sunflowers	F/G	45-224	10.7	18.4-121.1	< 1	63.4-345.1	2.4
Pine-seed Orchards	G	-	-	1.5-7.6	< 1	1.5-7.6	< 1
Cranberries	G (WA/OR)	-	-	0.4	< 1	0.4	< 1
Small Grains							
Wheat	F	80-165	9.7	-	-	80-165	1.4
Barley	F	Negligible	-	-	-	-	-
Oats	F	Negligible	-	-	-	-	-
Alfalfa	F	390-785	46.6	-	-	390-785	6.8
Grapes	F/G (CA)	-	-	18	< 1	18	< 1
Potatoes	F/G	44-87	5.2	108	1.5	152-195	2.0
Sugar beets	G	-	-	48	< 1	48	< 1
Sugarcane	F/G	-	-	6-12	< 1	6-12	< 1
Peppers	G	-	-	NA ²	-	NA	-
Strawberry	F (WA/OR)	-	-	-	-	-	-
Ornamentals	F	-	-	NA	-	NA	-
Cucurbits	G	-	-	NA	-	NA	-
Siberian Elm	G	-	-	NA	-	NA	-
Cottonwood	G	-	-	NA	-	NA	-
Banana	G (5G)	-	-	NA	-	NA	-
TOTALS		859-1661	100	5953.6-8763.1	100	6812.6-10424.1	100

¹ F=Flowable and G = Granular² NA=Not amifiable

In other cases, both formulations may be registered for use at the same time during the growing season. Because of these problems, determining the amount of ai of the two carbofuran formulations used on a particular crop can be difficult.

For simplicity, this analysis assumed that for all sites for which both carbofuran formulations are registered, all usage was assumed to be the granular formulation. This assumption may overstate the average site usage of granular carbofuran by 10 to 15 percent; thus, overstating potential benefits.

B. Benefits Assessment of Use Sites

The Agency reviewed information regarding the pests associated with 10 crops, methods of application of carbofuran, agricultural practices, and chemical and nonchemical alternatives to carbofuran. Several sources were used in the analysis, including publications, published State recommendations, public comments, company-submitted data, U.S. Department of Agriculture reports, information from State extension personnel, an Agency cooperative agreement (University of Illinois), and others. The general approach was to collect and review relevant information and current research (U.S. Environmental Protection Agency 1987f).

In addition to assessing currently available chemical and nonchemical pest control technologies, the Agency has sought to identify newly emerging integrated pest management (IPM) strategies that may impact on the future benefit of carbofuran use. These strategies are not factored into quantitative estimates of the benefits of carbofuran because research is ongoing. However, the information is provided as potential alternative agricultural practices. The Agency recognizes that there may be viable nonchemical alternatives that were not discovered in the available data bases and have not been considered in this analysis. EPA, therefore, encourages any persons with data they believe relevant to provide comments during the public comment period.

The economic impacts resulting from the cancellation of granular carbofuran were determined principally by using partial budgeting techniques. This analytical methodology usually employs judgment, expert opinion, and economic parameters developed by past research. A partial budgeting analysis is static and estimates economic impacts for a specific point in time. Economic variables such as input prices and the quality of the crop are usually assumed to be constant and assume that certain economic variables (e.g., farm prices for alternative insecticides or other productive inputs) would remain

constant and unaffected by regulatory action. Changes in costs, yields, production, income, and prices are compared to other economic indicators such as overall costs of production, gross and net income, and the total value of production to determine their relative significance.

1. Field Corn

The greatest use of granular carbofuran is on field corn, which represents approximately 58 percent of the total annual usage of carbofuran and 68 percent of all granular carbofuran usage. Carbofuran is also registered for use on sweet corn, although usage is minor. Approximately 4.5 to 5.5 million lb ai of granular carbofuran is applied annually to 4.5 to 5.5 million acres of field corn or 5 to 7 percent of the total crop in the United States.

Carbofuran 10G and 15G are registered for use in field corn to control the corn rootworm complex (northern, western, and southern corn rootworm), the corn borer complex (European and southwestern corn borer), common stalk borer, seed corn maggot, southern corn billbug, flea beetles, wireworms, and nematodes such as the sting, stubby-root, lesion, and lance nematodes. However, the corn rootworm and corn borer complexes are the major pests for which carbofuran is used. Some carbofuran labels also claim that carbofuran suppresses certain plant diseases by suppressing pests that are vectors of plant diseases.

Also, three Special Local Need (SLN) registrations permit the use of 10G and 15G in Florida to control lesser cornstalk borer and in Hawaii to control leafhoppers on field corn.

Northern and western corn rootworm larvae and adults both cause economic damage to corn. They overwinter as eggs, which hatch in the late spring or early summer. The newly hatched larvae feed on developing corn roots, which may result in decreased yield or plant lodging depending on the extent of damage.

The southern corn rootworm, however, overwinters as an adult under crop refuse. It becomes active in the spring and lays its eggs in the soil next to the host plant. The newly hatched larvae burrow into the roots, stems, and other parts of the plant and may feed externally on the roots.

The European corn borer overwinters as larvae, which pupate in late spring. Adult moths appear in May or June and lay their eggs. The young larvae hatch from the eggs and feed on the leaves and then on the leaf sheaf and whorl, which may cause damage to the unfolding tassel.

Older larvae tunnel into the stalk and ears, resulting in broken stalks and tassels, poor ear development, and dropped ears. Davidson and Lyon (1979) estimated that one borer per stalk may reduce yields 2 to 3 bushels per acre.

The southwestern corn borer overwinters as full-grown larvae in the bases of corn stubble. Pupation occurs in early June and adults emerge about a week later. The females deposit eggs on the leaf surface. Newly hatched larvae feed on the leaves, severing the terminal bud causing dead tissue in the center of the plant. They also tunnel into the stalks and ears, which results in stalk breakage.

Carbofuran is applied to control these pests and the others using the following four application methods:

At-planting in-furrow application - When seeds are planted, carbofuran granules are applied by being dropped into the furrow along with the seeds and mixed with the covering soil.

At-planting band application - Application is made by applying a 7-inch band ahead of the planter press wheel. The granules are incorporated into the top 1 inch of the soil by dragging a short chain or by using special covering devices. For nematode control a 7- to 14-inch band may be applied and incorporated into the top 3 inches of the soil by using a spring tine or drag chain.

Postemergence band application - After the seedlings have emerged, granules are applied as a band over the top of the row or along one or both sides of the row and incorporated into the soil using a disk or possibly a tine.

Foliar application - Granules are broadcast over the plant aerially or with ground equipment by directing the granules into the whorl. Foliar application is not permitted if more than 1.0 lb ai/A based on a 40-inch row space was previously applied at planting. If less than 1 lb ai/A was applied, a second application is permitted. No more than two foliar applications are permitted per season.

All major corn-producing States list carbofuran and its major alternatives in their guidelines for insect control. Several also list these pesticides for nematode control as well.

In the Corn Belt States of the Midwest, which includes Iowa and surrounding States, granular carbofuran is used mainly to control the corn rootworm complex and the European corn borer. In the Southeast and Southwest, carbofuran is used to control the southern corn rootworm and in the Southeast to control nematodes.

For control of soil-inhabiting insect pests, nematodes, and the first-generation European corn borer, granular carbofuran is applied to the soil at-planting (in-furrow or band application) or postemergence (band application). For second-generation corn borer control, carbofuran is applied over the top of the plant when corn is 18 to 24 inches in height up to the tasseling stage. Generally, application occurs from mid-March to mid-May.

Use rates vary according to pest (Table III-2). Based on 40-inch row spacing of field corn, the most common application rate is 1 lb ai/A.

The economically viable alternatives for granular carbofuran use on corn rootworm and borer complexes are listed below:

<u>Pest</u>	<u>Alternative</u>
Corn rootworm complex	Terbufos, chlorpyrifos, fonofos, trimethacarb, phorate
Corn borer complex	Permethrin, fonofos, phorate, chlorpyrifos,

The alternatives registered for nematode control include terbufos, ethoprop, and others.

Table III-3 summarizes the application methods and the most common application rates for these alternatives for nematode, corn rootworm, and corn borer complex control. In general, alternatives are available and used with the same application methods as carbofuran.

Carbofuran and its alternatives were evaluated in small-plot yield performance studies and analyzed for yield performance (Appendix 14). These alternatives included chlorpyrifos, ethoprop, ethion, diazinon, fonofos, phorate, terbufos, and trimethacarb. The studies were submitted by FMC Corporation and the States of Iowa, Illinois, Indiana, and Nebraska. Carbofuran and the alternatives were applied at planting using comparable application rates to control northern and western corn rootworm. All studies were reviewed, but only 131 were accepted and analyzed. The others were rejected because of one or more of the following reasons:

- o Yield data were inconsistent and resulted in untreated check yields equalling or exceeding all treatments, or untreated check plot root ratings and yields were higher than treatments;

Table III-2
Rates and Methods of Application of
Carbofuran in Field Corn

<u>Pest</u>	<u>Application¹</u>
<u>Insects</u>	
Armyworm (4-6 weeks)	1.0 lb ai/A
Cutworm	At-planting, in-furrow
First-generation European corn borer	
Flea beetle	
Corn rootworm complex	
Seed corn maggot	
White grubs	
Wireworms	
Second- and third-generation southwestern corn borer	1.5-3.0 lb ai/A At-planting, in-furrow
Common stalk borer	2.0-3.0 lb ai/A
First-generation European corn borer	At-planting, in-furrow
Leafhopper	
Southern corn billbug (Southeastern States)	
Armyworm (4-6 weeks)	1.0 lb ai/A
Cutworm	At-planting, 7-inch band
First-generation corn borer	
Flea beetle	
Corn rootworm	
White grubs	
Wireworms	
Third-generation southwestern corn borer	1.5-3.0 lb ai/A At-planting, 7-inch band
Common stalk borer	2.0-3.0 lb ai/A
First-generation European corn borer	At-planting, 7-inch band
Northern and western corn rootworm	1.0 lb ai/A Postplant, band over-the-row, side-dress, or both sides of the row

¹ Application rates based on 40-inch row spacing.

Table III-2

Rates and Methods of Application of
Carbofuran in Field Corn (cont'd)

<u>Pest</u>	<u>Application¹</u>
<u>Insects (cont'd)</u>	
Second-generation European corn borer	1.0 lb ai/A ² Postplant, aerial, or ground
Southwestern corn borer	broadcast foliar application

¹ Application rates based on 40-inch row spacing.

² Foliar application not permitted if more than 1.0 lb ai/A based on 40-inch row spacing was previously applied at planting. If less than 1.0 lb ai/A was applied at planting, a second application is permitted. No more than two foliar applications are permitted per season.

Table III-3

Rates and Methods of Application
of Carbofuran Alternatives in Field Corn*

<u>Alternative</u>	<u>Application</u>
<u>Corn rootworm complex</u>	
Terbufos	1.0 lb ai/A At-planting as band or in-furrow application
Fonofos	1.0 lb ai/A At-planting or at cultivation, band, or preplanting broadcast application
Chlorpyrifos	1.0 lb ai/A At-planting as band or in-furrow application, at cultivation as over-the-row or side dress, or preplant broadcast application
Phorate	1.0 lb ai/A At-planting band as over-the-row, behind the planter shoe, or in front or behind the press wheel application or postemergence broadcast over the top of the plants
Trimethacarb	1.0 lb ai/A At-planting as a 6- to 8-inch band and incorporated into the soil or as a band over-the-row at cultivation
<u>Corn borer complex</u>	
Fonofos	1.0 lb ai/A Postemergence broadcast as 6- to 8-inch band application using air or ground equipment
Chlorpyrifos	1.0 lb ai/A Postplant by aerial or ground broadcast application

*Application rates based on 40-inch row spacing.

Table III-3

Rates and Methods of Application
of Carbofuran Alternatives in Field Corn* (cont'd)

<u>Alternative</u>	<u>Application</u>
<u>Corn borer complex (cont'd)</u>	
Phorate	1.0 lb ai/A Prior to tassel emergence broadcast into the whorl application
Permethrin	0.1-0.2 lb ai/A Postemergence broadcast into the whorl or over-the-plant application

* Application rates based on 40-inch row spacing.

- o Rootworm pressure was low or nonexistent;
- o Rows of experimental plots contained skips;
- o Statistical analysis was not conducted on yield data;
- o Plots were exposed to long periods of inclement weather; and
- o Studies were designed to determine the effect of carbofuran on root pruning by rootworm larvae and did not include yield effects.

A statistical analysis was performed on the data by using the following methods and procedures (Appendix 14):

- o All data were sorted by State;
- o All data were run by the Statistical Analysis System;
- o All data were tested for normality;
- o Transformation was performed to data that were not normal; and
- o Duncan's Multiple Range Test at 0.05 level was calculated for the difference between mean yields.

The results of the statistical analysis indicated no statistically significant differences among treatment yields in the FMC-submitted data, nor were there statistically significant differences among treatment yields in the data submitted by the States of Iowa, Illinois, Indiana, and Nebraska. From the results of the statistical analysis, the Agency concludes that when carbofuran and/or its alternatives are applied to control the corn rootworm complex, no statistically significant differences in yield occur.

The Agency reviewed information concerning the efficacy of carbofuran for nematode control as well. Review of such data in terms of yield must take into consideration that application for nematodes also has a soil insecticidal effect, and separation of nematicidal from insecticidal yield effect is not possible. Thus, benefits are assigned to a combination of effects. Another factor in the interpretation of efficacy of carbofuran is the possible resistance of nematodes to carbofuran. Field tests and laboratory studies indicate that at least the corn lesion nematode has developed resistance to the compound (Smolik 1978).

Efficacy and comparative performance data were gathered from the American Phytopathological Society's annual publication entitled "Fungicide and Nematicide Test Results" (1965 to 1985). Test results were expressed in terms of populations of nematodes and yield. Inspection of the results for yield and numbers of nematodes indicated no consistent differences in performance between carbofuran, ethoprop, and terbufos. The data also indicated no consistent correlation between numbers of nematodes and yield. Yields from treated plots were statistically significant from the nontreated plots in about 58 percent of the tests.

In addition to assessing the efficacy of carbofuran and some of its alternatives, the Agency also evaluated aspects of carbofuran use that are not quantifiable. For example, carbofuran has systemic activity, remains active for a long period of time, and has a broad spectrum of control. Carbofuran may be used in rotating organophosphate with carbamate insecticides to potentially delay the development of resistance in soil pests, although the Agency recognizes that there may be some potential for organophosphate and carbamate cross-resistance. Also, repeated use of carbofuran may lead to an apparent increase in soil microbes capable of reducing its effectiveness.

In addition to treating field corn with carbofuran or its chemical alternatives, State extension personnel recommend non-chemical methods of control such as crop rotation, early planting, and others.

Crop rotation with soybeans is used for controlling rootworms. Northern and western corn rootworms are host-specific and if corn is not available, they will die. For this to be effective, soybeans must be free from volunteer corn that may be attractive to adult corn rootworms. For a small percentage of the acreage affected by Northern corn rootworms, 1-year rotations may not be adequate due to the occurrence of a 2-year diapause in some populations.

For corn borers, early planting is recommended, which increases the potential for first-generation corn borer infestations. These infestations are easier to control. Also, corn varieties resistant to the first-generation corn borer have been developed and will produce higher yields despite borer damage. However, resistance to the second-generation corn borer has not been successfully incorporated into a commercial variety (Bergman and Edwards 1986b).

Scouting for adult corn rootworm beetles is also recommended and used to predict potential problems in the following growing season. Generally, scouting is a survey tool

used by extension experts, consultants, and growers to determine if pests are present in crops and whether their numbers have reached a level that would warrant pesticide treatment. Since carbofuran is applied at planting, scouting is used at the end of the season to predict potential infestations that may occur during the following growing season and to determine whether or not at-planting treatment is recommended (Bergman and Edwards 1986a).

Reduction of corn borer populations may also occur by (1) rotating with sorghum; (2) low cutting of stalks, which removes hibernating larvae from the field; and (3) dislodging stubble in the fall to expose overwintering larvae.

In seeking out newly emerging pest control technologies related to field corn, the Agency concentrated on the corn rootworm complex and the European corn borer.

For the corn rootworm complex, four control strategies have had encouraging results and warrant continued monitoring.

Pheromone Mating Disruptants - Research investigating the use of pheromones to disrupt behavior of adult corn rootworms is currently being conducted, and the results are encouraging (Sutter 1986). Although certain difficulties associated with attaining a formulation providing adequate duration of release have been encountered, advances have been made.

Midseason Aerial Spray - Adult populations are killed before they have the opportunity to lay eggs, which reduces the numbers of injurious larvae in the soil the following season. This method has never found widespread acceptance due to control failures and the need for intensive pest scouting. However, research designed to identify the causes of the control failures is underway at several universities (Kuhlman 1986). Changing the timing of application or a similar refinement may produce a viable control strategy.

Parasitic Nematodes - Field trials are being conducted with a nematode species (Neoaplectana carpocapsae). Earlier trials have shown control potential in both laboratory trials and limited field evaluations (U.S. Department of Agriculture 1985).

Semiochemical Toxic Baits - Either or both a pheromone and a keromone are used to attract adult rootworms to a bait containing a low dose of a conventional insecticide (Sutter 1986). Two years of U.S. Department of Agriculture field trials have indicated that low rate applications of these formulations

attract and kill sufficient numbers of adult rootworms to reduce egg laying below economic threshold levels. The economic threshold is the amount of pest damage or the number of pests a crop can tolerate before economic loss occurs. A benefit of this strategy is that naturally occurring pollinators, predators, or parasites are not affected. Midseason applications of more conventional control methods may be accompanied by later outbreaks of secondary pests due to the elimination of naturally occurring controls.

For the European corn borer, many control strategies have been tried and discarded while others such as scouting to determine economic thresholds are common. The Agency was unable to identify any newly emerging technologies that are not already common knowledge within the agricultural community. Research over the years has indicated that a larval parasite (Lydella thompsoni) and an egg parasitoid (Trichogramma nubilale) can be effective in the control of the European corn borer (Burbutis and Kopke 1981; Burbutis et al. 1984; Romig et al. 1985). EPA believes that, even at current levels of technology, areawide release programs could be beneficial and encourages additional research in this area.

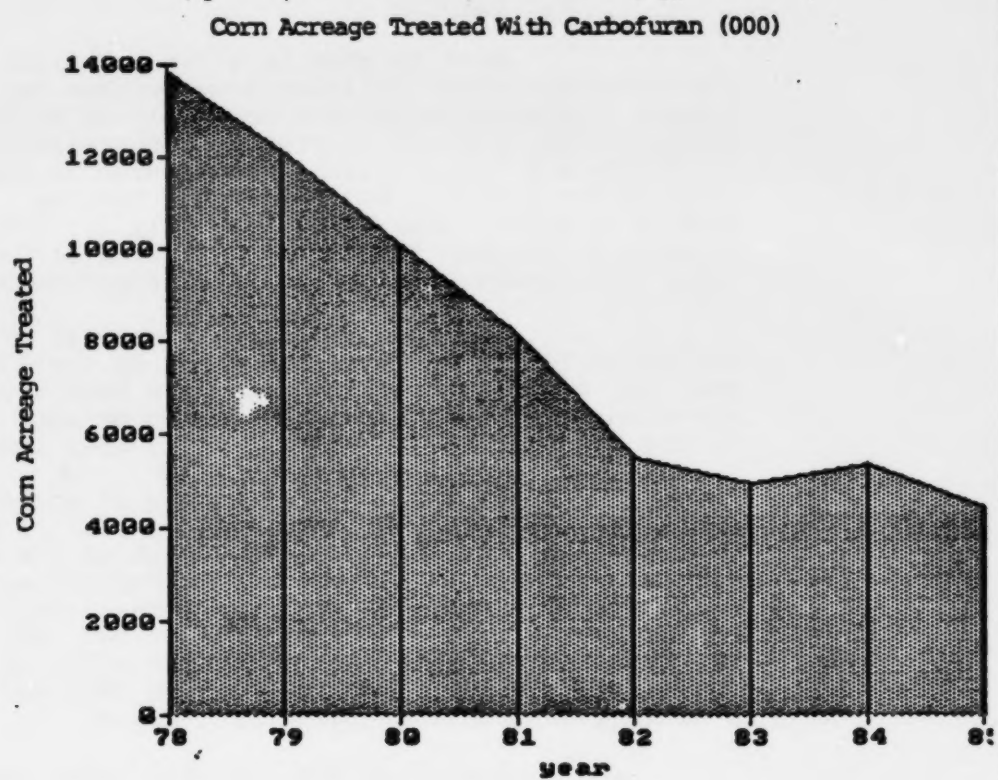
Regarding the economic impacts of a cancellation of granular carbofuran, the Agency used partial budgeting techniques to estimate impacts. The field corn insecticide market is highly competitive with several alternatives available that are comparable in both product performance and cost per acre treatment. Although cancelling granular carbofuran would reduce the number of alternatives available for corn rootworm and corn borer control, cost effective alternatives are available.

Without granular carbofuran, any changes in the cost of production would be less than 1 percent in total variable production costs for individual growers using carbofuran. Cost effects will only reflect differences in the cost of pesticides since there will be no change in application costs or equipment with the use of granular alternatives. Given information on the current soil insecticide market, terbufos and chlorpyrifos would be likely substitutes for carbofuran. Since trimethacarb would be the only remaining carbamate insecticide, trimethacarb would also be likely to replace carbofuran to some extent. The choice of an alternative chemical, however, is an individual decision based on the presence of target pests, growers' perception of efficacy, recommendations of local and State extension service personnel, previous experience, and market factors.

Carbofuran was the leading insecticide used on field corn at one time. Since 1978, the carbofuran market has been declining, and usage is approximately one-third the level it was in 1978 (Figure III-1). However, it continues to be the most widely used insecticide for control of corn borer infestations.

III-14

Figure III-1



Source: EPA estimate

Carbofuran lost its market share primarily to terbufos and chlorpyrifos. By 1986 the market share held by carbofuran dropped to less than 15 percent, where it ranked fourth in terms of acre treatments out of the five major field corn insecticides. It is not clear why the use of carbofuran has declined so rapidly, but reasons could include loss of effectiveness, spectrum of pests controlled, and others.

The downward trend in carbofuran usage may be attributable to the declining corn rootworm market for carbofuran. In general, it appears that overall insecticide treatments for corn rootworm are declining, with carbofuran especially being used less to control these insects.

2. Sorghum

Most sorghum is grown for grain and used primarily for livestock feed, although some sorghum is also produced for forage. Carbofuran is used primarily as an at-planting band or in-furrow application to protect young plants from later greenbug or chinch bug infestations. Carbofuran is applied at 0.75 to 1.0 lb ai/A for greenbug and chinch bug control. Application generally occurs from April 1 to July 1. Use is limited to grain sorghum or sorghum for forage. Grazing or harvesting sorghum grown for forage within 75 days of application is not permitted.

In 1985, 1.1 billion bushels of sorghum were harvested in the United States from 16.7 million planted acres. Both the production and acreage have been trending upward and represent all-time highs. Depending on pest levels, carbofuran is the first or second most commonly used insecticide on sorghum.

Sorghum use represents 11 percent of the total annual usage of carbofuran and 14 percent of all granular usage. Approximately 480,000 to 1,500,000 lb ai are applied annually for insect control to 640,000 to 2,040,000 acres or 4 to 12 percent of the U.S. sorghum crop. The lower end of these ranges is indicative of the normal infestations, while the upper end of the range is for years of high infestation levels. High level of use was evident in 1980 and 1981 and occurs about every 5 to 10 years under dry growing seasons.

Greenbugs are the major pest and damage sorghum by sucking plant juices from plant. In the process of feeding, they also inject a toxin into the plant. The chinch bug also extracts juices from the plant. As the sorghum plant grows larger, chinch bugs become more difficult to control because they stay near the base of the plant where they are less vulnerable to insecticides.

Sorghum has received considerable IPM attention. Due to the relatively low return on sorghum, a number of pest management and cultivation practices have already been incorporated into sorghum culture to reduce the need for pesticide application. None of these practices will completely replace the use of insecticides on sorghum, but they will help reduce the number of applications and the amount of insecticides used.

Sorghum varieties resistant to greenbugs and to chinch bugs are commercially available. Based on conversations with extension experts (U.S. Environmental Protection Agency 1987f), these varieties are widely used by growers and their use is stressed in State recommendations. These varieties tolerate a higher amount of damage before economic injury levels are reached and a pesticide application is needed. In the early 1980's, a number of greenbug-resistant sorghum varieties became ineffective when greenbug Biotype E evolved. Since that time, varieties that are resistant to this biotype have become available, but the grower must be careful when choosing a sorghum variety because sorghums offering resistance only to Biotype C are also on the market.

In addition, a braconid parasite (Lysiphlebus testaceipes) has been demonstrated to parasitize greenbug populations causing population collapse (Sekar 1957; Wood and Chada 1969). Overwintering populations of the parasite, however, are frequently ineffective at controlling the greenbug due to the greenbug's ability to reproduce at lower temperatures and its shorter life cycle. Early releases of the parasite (Starks et al. 1976) indicated that inoculative releases were feasible and control was achievable. Yield data indicated that the resulting control was comparable to control achieved with pesticide application. However, the cost for a release program was high. Additional research may be able to bring the cost within an acceptable range. Also, additional savings may occur by not having to treat for secondary pest outbreaks precipitated by the application of pesticides.

For greenbug control, pesticides may be applied as a preventative treatment at the time of planting or later in the season if problems with greenbugs arise. At-planting, alternatives include disulfoton, terbufos, and aldicarb. Terbufos is expected to be the most widely used substitute because disulfoton resistance problems have been reported in Kansas, Texas, Nebraska, and South Dakota. Terbufos is much less expensive than aldicarb and costs approximately \$8.40/A. Aldicarb cost is \$26 to \$27/A. Terbufos is also most often cited by extension experts as a possible alternative to granular carbofuran. In terms of product performance, terbufos appears to be as effective in greenbug control as carbofuran.

Economically viable alternatives available for use later in the season include carbofuran 4F, chlorpyrifos 4E, and dimethoate 4E. This is recommended in areas with sporadic early greenbug populations or where the greenbug occurs several weeks after plant emergence.

For chinch bug control, carbofuran appears to be the most efficacious at-planting treatment available. Aldicarb, a possible alternative, is both more costly (an increase of approximately \$18 per acre) and less effective than carbofuran. Yield losses as great as 20 percent could be possible from the use of aldicarb during years of heavy infestation.

Partial budgeting techniques based upon costs and efficacy of the most likely alternatives were used to evaluate the economic impacts from a cancellation of granular carbofuran use on sorghum. In areas where granular carbofuran is used as an at-planting treatment for greenbug control, terbufos is expected to be the most likely replacement and is as cost effective as carbofuran. Cancellation would not have an adverse effect on sorghum producers (at most \$0.4 to \$0.9 million annually) or consumers.

In years of high chinch bug infestations, aggregate cost increases and the value of yield reductions could range from \$7.4 to \$9.3 million in eastern Kansas, if aldicarb is used. These impacts, however, do not consider the foliar treatments available for use later in the season. Foliar treatments may not always provide adequate control because of problems with treatment timing, limited availability of scouts, and chinch bug reinfestations. The economic impacts associated with high chinch bug infestations would be localized with the burden of loss borne mostly by the growers if foliar treatments are not used.

3. Soybeans

Soybean use represents 4 percent of the total annual usage of carbofuran and 5 percent of granular usage. Approximately 265,000 to 485,000 lb ai are applied to less than 1 percent or 210,000 to 280,000 acres of U.S. soybeans. Carbofuran is used primarily in the East/Southeast to control the Mexican bean beetle and various nematodes such as root-knot, stubby root, and cyst nematode.

Registrations for carbofuran 10G and 15G products permit a single 7-inch band or in-furrow application at planting of 1.5 to 2.0 lb ai/A or a single in-furrow application of 1.0 to 1.5 lb ai/A for Mexican bean beetle and nematode control. These application rates are based on 40-inch row spacing. Application generally occurs from May 1 to July 15.

The larvae and adults of the Mexican bean beetle damage soybeans by feeding on the foliage. Damage is most critical during bloom, pod set, and pod fill. Researchers (U.S. Environmental Protection Agency 1987f) indicate that the soybean plant can withstand 30 percent defoliation before the plant reaches these stages without any loss in yield.

In the majority of the soybean-producing States, the Mexican bean beetle is not a major pest and is only of major concern in some of the southeastern States (Davidson and Lyon 1979). Although granular carbofuran is registered for Mexican bean beetle control, only the States of Florida, Kentucky, and Virginia list carbofuran in their recommendations. The report by the National Agricultural Pesticide Impact Assessment Program (1985) indicated that approximately 19 percent of Maryland and Delaware soybean fields were treated with granular carbofuran. Because carbofuran is applied at planting, it is uncertain whether enough carbofuran will be present in the plant to control an infestation at pod set and fill, the critical stages of Mexican bean beetle infestation. (Pod set and fill do not occur until mid or late summer). Thus, consultants and extension entomologists in the majority of the soybean-producing States recommend the use of foliar sprays later in the season to control the Mexican bean beetle.

Economically viable alternatives for Mexican bean beetle control may be applied at-planting and include aldicarb, disulfoton, and phorate. Viable insecticides applied later in the season include permethrin, methyl parathion, carbaryl, and methomyl. Viable alternatives for nematode control include aldicarb, ethoprop, and fenamiphos.

The Agency evaluated small plot yield performance studies for comparative performance of granular carbofuran, aldicarb, disulfoton, phorate, and terbufos on soybeans for Mexican bean beetle control (Hammond 1981; Linduska et al. 1982; Linduska et al. 1983). These studies indicate that the plots treated with aldicarb, disulfoton, and terbufos had the greatest yields in bushels per acre (bu/A). They also indicated that defoliation of soybeans by Mexican bean beetle did not always affect yields. Based on the review of these studies, aldicarb and disulfoton are effective in controlling the Mexican bean beetle.

Use of resistant varieties of soybeans, early planting, and crop rotation are also recommended. In addition, the annual release of a Eulophid wasp (Pediobius foveolatus) has provided successful control of the Mexican bean beetle as well (Stevens et al. 1975).

Nematodes typically infest soybeans grown in the sandy soils of the Southeast. Chemical control of soybean nematodes occurs in these areas when the use of resistant varieties and crop rotation are not practical or effective (Gazaway and Henderson 1983). Crop rotation requires a 3- to 4-year program during which time susceptible crops cannot be planted, and susceptible weeds must be controlled. Resistant varieties have been demonstrated to lose resistance, and resistance to one nematode does not necessarily convey resistance to other nematodes. The economically viable alternatives for carbo-furan's nematicidal use for soybeans are granular formulations of aldicarb, ethoprop, and fenamiphos.

For simultaneous control of insects and nematodes, carbofuran is applied in areas that have high risk for Mexican bean beetle and nematode infestations. How often both are a problem is not predictable. While aldicarb is not expected to be the most viable alternative for growers with only nematode problems, growers with both nematode and Mexican bean beetle problems are likely to use aldicarb.

Other registered alternatives for nematicidal use include 1,3-dichloropropene, methyl isothiocyanate plus 1,3-dichloropropene, sodium methyldithiocarbamate, and carbofuran 4F.

Carbofuran has been field tested as a soybean nematocide since about 1970. The Agency reviewed efficacy and comparative performance data in the annual publications of the American Phytopathological Society's Fungicide and Nematicide Test Results 1965 to 1984. From among 60 individual reports on nematicide evaluations for soybeans, 26 dealt with evaluations of carbofuran and certain alternatives. Several of the tests compared performance of nematicides tested in plots planted to nematode susceptible and resistant soybean varieties. Results were expressed in terms of yield (bushels of beans harvested/A). The field tests were conducted in several regions of the country under a wide range of environmental conditions, nematode infestation levels, and cultural practices. Data from most of the test results were subjected to statistical analyses. Although consistent differences in yield among treatments and between the untreated and individual treatments were often apparent, differences were not always statistically significant.

In 14 trials of direct comparison, the average yield from untreated plots planted to susceptible varieties was 16.2 bu/A compared with 25.3 bu for nontreated plots planted to resistant varieties, a difference of 9.1 bu. In 18 direct comparison trials planted to susceptible varieties, the average yield for carbofuran treatments averaged 26.1 bu/A compared with

Applications begin in late winter and are scheduled at 30- to 60-day intervals. These applications will continue into late summer. Aerial application is preferred because of better coverage, lower application rates, lower human exposure, and less drift. The timing of application is critical and is normally scheduled by using pheromone traps that monitor insect pest populations.

Experts indicate that the use of granular carbofuran on seed-producing orchards is limited and has declined significantly in recent years. The one major use still cited is for tip moth control on young grafted seedlings in the first 2 to 3 years of an orchard establishment.

Without carbofuran, it is anticipated that one treatment of fenvalerate followed by 1 to 2 treatments of azinphosmethyl would be the likely substitute. Control using the alternatives would average about the same as granular carbofuran. Depending on whether 1 treatment with fenvalerate followed by 1 to 2 treatments with azinphosmethyl are made, impacts could range from -\$37 to +\$22 per acre. At the high impact level, costs would increase by \$22 per acre per year. Given normal operating and maintenance costs for an orchard at \$750 to \$900 per acre per year, costs at maximum would increase 2 to 3 percent per year, but also could decrease by 4 to 5 percent.

Using the range of per acre cost changes, order-of-magnitude aggregate cost impacts can be estimated. Assuming 500 acres of pine seed orchards are treated annually with granular carbofuran, the range of aggregate impact is -\$18,500 to +\$11,000. This impact is relatively small in comparison to the annual economic value of seeds potentially produced from 10,000 acres at 40 lb/A valued at \$500 per pound or \$200 million. It is also small relative to the hypothetical market value seeds assuming \$60 per pound or \$24 million.

10. Sunflowers

The use of carbofuran on sunflowers represents 2 percent of annual usage and less than 1 percent of granular usage. Approximately 18,400 to 121,100 lb ai are used to treat 18,400 to 105,900 acres.

Carbofuran 15G is used in North and South Dakota to control the sunflower stem weevil; the sunflower beetle; and migratory, redlegged, two-striped, differential, and clearwinged grasshoppers. Use at planting may be made either as in-furrow or 7-inch band application. Application is 2.3 to 2.6 lb ai/A with 30-inch row spacing. In-furrow application is made by directing the granules into the planter shoe with the seed or by placing the applicator tube directly behind the planter shoe so that granules drop into the furrow and mix with the covering soil. Band application is followed by mixing the granules with the covering soil. Application is generally made May 1 to May 30.

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18.3 for the untreated. In two direct comparison trials planted to resistant varieties, the average yield for carbofuran treatments was 33.7 bu compared with 29.1 bu for the untreated, a difference of 4.6 bu. In direct comparison tests planted to resistant varieties, chemical treatments consistently demonstrated improved yield over the untreated.

The average yields (bu/A) in direct comparison tests from susceptible variety plots treated with carbofuran and its alternatives are summarized in the following table.

<u>Alternative Tested</u>	<u>Number of Trials</u>	<u>Alternative</u>	<u>Carbofuran 10G or 15G</u>	<u>Average Yield Difference</u>
Ethoprop	9	28.4	29.2	-0.8
Aldicarb	13	24.6	24.0	+0.6
Fenamiphos	11	24.3	24.5	-0.2
1,3-dichloro-propene + dichloropropane	4	23.2	21.8	+1.4
Oxamyl	3	43.3	43.6	-0.3

Given the limited number of comparative tests of treatments, the limitations comparing tests conducted under different conditions, and discounting insecticidal effects, the comparisons with susceptible varieties indicate the carbofuran alternatives ethoprop, aldicarb, fenamiphos, and oxamyl to be about equal in performance to carbofuran, and 1,3-dichloropropene plus dichlororpropane may be slightly superior in performance to carbofuran.

Only one or two direct comparison tests from resistant variety plots treated with carbofuran and alternatives were reported. Observation of these data indicates that nematocide treatment of resistant varieties results in improved yields.

Based on partial budgeting techniques, the economic impacts from cancellation were evaluated. No significant impacts are likely. There are numerous cost-effective alternatives available for control both at planting and as foliar sprays, which are not expected to have adverse impacts on production costs.

Overall, aggregate impacts are expected to be minor, amounting to less than 1 percent of the U.S. farm value of soybeans. Without carbofuran available for nematode control, the alternatives most likely to replace carbofuran could increase

total production costs as much as \$4.7 million to \$5.5 million, primarily in the Southeast, if aldicarb was used on those acres with both nematode and Mexican bean beetle problems. However, this is unlikely.

4. Rice

Approximately 2 percent of all carbofuran and granular carbofuran is used on rice in Arkansas, California, Louisiana, Mississippi, Texas, and a small amount in Missouri. About 319,000 acres (101,000 in California and 218,000 in Texas and the Delta region) are treated. In California, approximately 25 percent of the rice acreage and 10 percent in the other regions are treated with carbofuran. Approximately 160,000 lb ai are applied.

An SLN registration permits the use of 1 lb ai/A on drained rice fields in California if the fields were not previously treated with carbofuran during the growing season.

The rice water weevil is a major pest in rice and is the only economically important pest in rice directly related to the use of carbofuran, the only pesticide registered for its control (National Pesticide Information Retrieval System 1986). The 3G and 5G formulations of carbofuran are registered and marketed for control of this pest in the southern States of Arkansas, Louisiana, Mississippi, and Texas. The 3G formulation is also registered for use in Missouri. In California, the 2G and a 5G formulation are registered to control the rice water weevil.

Carbofuran is also registered for dark rice field mosquito control, but surveys indicate that it is not used for this purpose (U.S. Environmental Protection Agency 1986).

The rice water weevil is the major insect pest of rice in all rice-growing areas. In the spring, the adults will fly from their overwintering sites such as plant debris, grass clumps on levees, or ditchbanks to recently flooded rice fields. They will begin to feed on the leaves of the young rice plant. Although not causing economically significant damage at this stage, adult feeding causes scarring on the surface of the leaves, which is used as a marker to monitor infestations. The adults deposit their eggs on leaf sheath tissue at or below the water level. Plants close to levee margins are the preferred egg-laying sites. The newly hatched larvae leave the stem and continue their development in or on the rice plant roots. Severe root pruning results in stunted plants with fewer tillers, delayed maturity, and reduced grain yield.

Treatment for rice water weevil control varies among California and the southern rice-growing States. However, all control recommendations are based on annual population monitoring. In California, carbofuran is applied as a preventive, preplant, preflood broadcast application of 0.5 lb ai/A for fields that have perennially damaging rice water weevil populations. The applications should be limited to areas of the field where severe weevil damage was recorded during the previous season's monitoring programs. Scouting for rice water weevil damage indicates the severity of the infestations in untreated fields, and monitoring records indicate where to treat the following year. The label does not permit treating flooded fields in California.

In the southern rice-growing States, carbofuran may be applied as one broadcast application of 0.45 to 0.6 lb ai/A. Applications may be made 1 day prior to or up to 21 days after permanent flooding. However, postflood treatments are recommended. Treatment includes scouting, which should begin within a week of permanent flooding. The sampling for rice water weevil larvae should begin 1 to 2 weeks after the onset of permanent flood. Treatment is recommended when threshold levels are reached.

Applications of carbofuran may be made from late April through early July depending on weather conditions, which influence planting and permanent flooding dates.

The Agency identified two potential IPM strategies that may have future impact. The first concerns draining rice fields. Although not recommended at this time, evidence indicates that draining can control the rice water weevil (Morgan and Tugwell unpublished). While draining has been utilized in the past, it has been viewed as ineffective. What differentiates earlier draining techniques from the techniques now being proposed is timing. Field draining has historically been timed to coincide with the appearance of late instar larvae. The new approach times the field draining to coincide with early instar larvae, or approximately 10 days postflood. Field evidence suggests that it is efficacious in the control of the rice water weevil.

The Agency also recognizes that while providing an alternative to growers in certain areas, this technique may not be suited for use in other areas for a variety of cultural and economic reasons. These reasons may include the cost of pumping, the availability of water, and others. Nonetheless, growers should be encouraged to evaluate this technique against their own particular set of growing conditions.

The second IPM strategy suggests that one or more parasitic nematodes may be of benefit in the control of the rice water weevil (Bunyart et al. 1977). Little research, however, has been focused on their possible application. As a consequence, the Agency can make no judgment as to the potential viability of nematodes as a control technique. The Agency encourages further research in this area.

Yield losses due to rice water weevil infestations are documented from small plot tests summarized in Table III-4. Very few of these tests showed statistically significant difference in yield between carbofuran treated fields and untreated controls. Since severe damage usually occurs within 6 to 12 m of field margins and areas adjacent to levees, it is difficult to estimate full-field commercial losses (Grigarick 1984). Therefore, in the absence of statistically sound data, an estimate was made that if carbofuran was not available to rice growers, yields of those acres normally treated with carbofuran would be reduced by an average of 7 percent. This estimate was based on data from 24 small plot tests, which showed yield differences ranging from +0.77 to -22.97 percent when carbofuran was applied at the registered rate compared with yields obtained in untreated plots. The possibility of yield impacts increasing in succeeding years exists if no alternatives become available for controlling the rice water weevil. However, projections of these longer impacts cannot be made with available data.

Partial budgeting was used to evaluate the impacts of carbofuran cancellation on rice. Since no alternative chemical controls are currently available for the rice water weevil, growers are expected to incur direct annual gross revenue losses of \$14.9 million due to the estimated 7 percent yield loss. Because rice yields in California average 7400 lb/A, the value of yield loss would be \$60/A. The Delta region, with an average yield of 5000 lb/A, would lose approximately \$41/A. Since growers in California rely more heavily on carbofuran and treat 25 percent of the crop, they will incur a greater percentage of the overall loss.

Because no alternative chemical controls are available, pest control costs would decrease by approximately \$8.50/A or about 4 percent of the total variable operating costs in the Delta and 3 percent in California. With the \$2.7 million cost savings of not applying carbofuran, the annual net revenue loss for impacted growers is about \$12.2 million, with per acre losses averaging \$52 in California and \$32 in the Delta. The \$12.2 million impact on the rice industry amounts to approximately 10 percent of the net farm income of the impacted acres. Some marginal rice growers who normally rely on carbofuran may be forced out of production.

Table III-4
Yield Differences in Rice

<u>Treatment</u>	<u>Formu- lation</u>	<u>Application Rate</u>	<u>Treated Yield</u>	<u>Untreated Control</u>	<u>Difference</u>	<u>Percent Increase/ Decrease</u>
<u>Arkansas:</u>						
<u>1981 (Morgan et al. 1982)</u>						
Preflood	3G	0.45 lb ai/A	7535	7161	374 NS*	-4.96
Preflood	3G	0.6 lb ai/A	7425	7161	264 NS	-3.56
Postflood	3G	0.6 lb ai/A	6216	6026	190 NS	-3.06
<u>1982 (Morgan et al. 1984)</u>						
Preflood	3G	0.6 lb ai/A	6535	6349	186 NS	-2.85
Postflood	3G	0.6 lb ai/A	7019	6849	170 NS	-2.42
(5 days)						
Postflood	3G	0.6 lb ai/A	6891	6821	70 NS	-1.02
(5 days)						
<u>Louisiana:</u>						
<u>1974 (Gifford et al. 1975)</u>						
<u>Trial 1</u>						
Postflood	3G	0.5 lb ai/A	4295	4209	86 NS	-2.00
(1 week)						
Postflood	3G	0.5 lb ai/A	4484	4209	275 NS	-6.13
(2 weeks)						
Postflood	3G	0.5 lb ai/A	4455	4209	246 NS	-5.52
(3 weeks)						
<u>Trial 2</u>						
Postflood	3G	0.5 lb ai/A	4770	4370	400 NS	-8.39
(1 week)						
Postflood	3G	0.5 lb ai/A	4930	4370	560**	-11.36
(2 weeks)						
Postflood	3G	0.5 lb ai/A	4719	4370	349 NS	-7.40
(3 weeks)						
<u>1980 (Robinson et al. 1981a)</u>						
Preflood	3G	0.5 lb ai/A	6159	5540	619 NS	-10.05
Postflood	3G	0.5 lb ai/A	6455	4972	1483**	-22.97
<u>1981 (Robinson et al. 1981b)</u>						
Postflood	3G	0.5 lb ai/A	6862	6654	208 NS	-3.03
Postflood	3G	0.5 lb ai/A	5956	5156	800**	-13.43
Postflood	3G	0.5 lb ai/A	6774	5056	718**	-10.60

*NS = Not significant.

**Significantly different from the untreated check at $p = 0.05$.

Table III-4

Yield Differences in Rice (cont'd)

<u>Treatment</u>	<u>Formu- lation</u>	<u>Application Rate</u>	<u>Treated Yield</u>	<u>Untreated Control</u>	<u>Difference</u>	<u>Percent Increase/ Decrease</u>
<u>Louisiana (cont'd)</u>						
<u>1982 (Robinson et al. 1982)</u>						
Postflood	3G	0.5 lb ai/A	8181	7433	748**	-9.14
<u>1983 (Robinson et al. 1983)</u>						
Postflood	3G	0.5 lb ai/A	8103	7155	948	-11.70
Postflood	3G	0.5 lb ai/A	7976	6766	1210	-15.17
<u>1984 (Robinson et al. 1984b)</u>						
Postflood	3G	0.5 lb ai/A	3396	3422	26NS	+0.77
<u>1984 (Robinson et al. 1984a)</u>						
Postflood	3G	0.5 lb ai/A	6946	6685	261	-3.76
Postflood	3G	0.5 lb ai/A	7478	7076	402	-5.38
<u>California:</u>						
<u>1980 (FMC Corporation, Comment #7 submitted in response to PD 1)</u>						
Preflood	Unknown	0.5 lb ai/A	7170	6929	241 NS	-3.36

**Significantly different from the untreated check at $p = 0.05$.

Under the current U.S. Department of Agriculture farm program, it is estimated that government payments will decrease by \$6.1 million because of lower production. An estimate of the loss to society is \$6.1 million, which is derived from the rice industry impact of \$12.2 million less the reduced government payments of \$6.1 million. Short-term consumer price increases are possible, but could not be quantified.

Long-term economic effects from a cancellation of carbofuran would depend upon possible pest population increases and the market availability of cost-effective alternatives in the future.

5. Peanuts

Carbofuran use in peanuts represents 5 percent of the total annual usage and 5 percent of the granular usage. Approximately 218,300 to 573,000 lb ai are applied to 136,500 acres or 9 percent of the U.S. crop. All major peanut growing regions account for some use. Granular carbofuran is used to control insect pests including thrips, potato leafhopper, and southern corn rootworm. Additional usage is for several nematode species including root-knot, sting, stunt, lesion, and ring nematode.

Carbofuran 10G and 15G may be applied for insect and nematode control. Treated peanut forage may not be fed to dairy animals or animals being finished for slaughter. Based on 36-inch row spacing, carbofuran may be applied as follows:

<u>Application</u>	<u>Pest</u>	<u>Application Rate</u> <u>(lb ai/A)</u>
At-planting, in-furrow	Thrips	0.5-1.0
	Potato leafhopper	
	Southern corn rootworm	
Before planting, band	Thrips	2.0-4.0 (12" band)
	Potato leafhopper	3.0-5.0 (18" band)
	Southern corn rootworm	
Before planting, band	Nematodes	2.0-4.0
At-pegging,* band	Southern corn rootworm	1.0-2.0 (14-18" band)

*Pegging refers to the early pod and seed development stage. The stage generally occurs 60-90 days after planting.

SLN registrations also permit the use of 10G and 15G in New Mexico to control thrips and nematodes.

Several species of thrips, such as western flower thrips, may attack peanuts. Both nymphs and adults cause damage by rasping plant tissue and sucking juices from the leaves, causing wrinkling of leaflets and stunting plants.

Potato leafhopper nymphs and adults suck the plant juices from the conducting vessels of the plant. Damage includes spotting, yellowing, leaf curling, stunting, and browning of foliage, which may cause a reduction in yield and quality of the nuts.

The southern corn rootworm becomes active in the spring and lays eggs in the soil near the host plant. The newly hatched larvae burrow into the roots, crowns, and stems, or may feed externally on the roots of the peanut plant. This pest is especially serious in the southern States.

For insect control in peanuts, economically viable alternatives include aldicarb, disulfoton, chlorpyrifos, fonofos, and phorate. Viable alternatives for nematode control include aldicarb, ethoprop, and fenamiphos.

Several small plot studies were conducted (Tappan and Gorbet 1981) over a 4-year period to determine the economics of tobacco thrips control with systemic pesticides on Florunner peanuts in Florida. Efficacy and economics of band and broadcast applications of granular carbofuran, aldicarb, and disulfoton from 1976 through 1979 were studied. Excluding the checks, thrips populations in terminal buds were highest in carbofuran treatments each year during the first 31 days of plant growth and were significantly ($p = 0.05$) higher than in aldicarb or disulfoton treatments in 1977 and 1979.

A significant reduction in percent thrips foliage injury for some treatments of aldicarb and disulfoton persisted for 80 days after planting, except for 73 days in 1979. All treatments, regardless of application method, produced a yield increase that was not statistically related to thrips control. The band application method was as efficacious as the broadcast method, and was more economical, since less material was required per acre. Profitable net returns were obtained each year, but losses occurred for aldicarb in 1977 and disulfoton in 1976 and 1978.

From the review of these studies, it appears that thrips infestations and their control on peanuts cannot always be correlated with yields when using granular carbofuran and its alternative. These studies also indicate that any decision by peanut growers to use granular carbofuran, aldicarb, or disulfoton should not be based entirely on the prospect of thrips control.

Since granular carbofuran and many of its alternatives used to control insect pests also have nematicidal properties and are registered and used as such, several of the studies examined were designed and conducted to determine the efficacy of these chemicals on both types of pests. Therefore, it was difficult to determine whether the yield effects presented in these studies can be definitively linked to their insecticidal or nematicidal properties, or both.

For nematode control, application is recommended only when soil assays indicate that nematode populations are high enough to affect yield. Soil samples are taken and nematodes extracted to determine the type and number. Treatments for nematode control are recommended at 2.0 to 5.0 lb ai/A. Economically viable alternatives include aldicarb, ethoprop, and fenamiphos. Other registered nematicides include oxamyl, sodium methyldithiocarbamate, and others.

Carbofuran has been field tested as a peanut nematocide since about 1965. The Agency reviewed efficacy and comparative performance data in the annual publications of the American Phytopathological Society's Fungicide and Nematocide Test Results for the years 1965 to 1984. From among 45 individual reports on nematocide evaluations for peanuts, 30 dealt with evaluations of carbofuran and certain alternatives. Results were expressed in terms of yield, pounds of peanuts per acre. The field tests were conducted in various southeastern and midsouthern States under a wide range of environmental conditions, nematode soil infestation levels, and cultural practices. Data from most of the test results were subjected to statistical analyses. Although consistent differences in yield among treatments and between the untreated plots and individual treatments were apparent, differences were often not statistically significant.

In 28 trials of direct comparison, the average yield from plots treated with carbofuran granular formulations was 2906.6 lb/A compared with 2307.4 lb for the nontreated controls, an increased yield of 599.2 lb for the carbofuran.

The average yields (lb/A) in direct comparison tests from plots treated with carbofuran and its alternatives are given in the listing below.

<u>Alternative Tested</u>	<u>No. of Trials</u>	<u>Alternative</u>	<u>Carbofuran 10G or 15G</u>	<u>Average Yield Difference</u>
Aldicarb	15	2894.0	3057.7	-163.7
Fenamiphos	15	3099.1	3042.6	+ 56.5
Ethoprop	19	2561.0	2863.8	-302.8

<u>Alternative Tested</u>	<u>No. of Trials</u>	<u>Alternative</u>	<u>Carbofuran 10G or 15G</u>	<u>Average Yield Difference</u>
Oxamyl	4	3328.0	3294.7	+ 33.3
1,3-dichloropropene	5	2472.8	3116.4	-643.6
Terbufos	6	3330.3	3378.2	- 47.9

Given the limitations of comparing tests conducted under different circumstances and discounting the insecticidal effects of the test compounds, the comparisons indicate that (1) carbofuran is superior in performance to ethoprop, 1,3-dichloropropene, and aldicarb; and (2) carbofuran is about equal in performance to fenamiphos, oxamyl, and terbufos.

Usage of carbofuran is about 36,500 and 100,000 acres for insect and for nematode control, respectively. This would indicate about 136,500 acre-treatments for both target pest groups across the three peanut-growing areas. With the information on change in chemical costs, the estimated change in pest control costs should carbofuran not be available can be calculated. The overall annual impact would not exceed \$4 million. Total variable costs of production would increase 4 to 6 percent for alternative insecticides and 7 to 11 percent for alternative nematicides.

The pesticides used as carbofuran replacements would depend on whether the target pests were insects or nematodes. The generally higher rate of application for nematode control leads to higher treatment costs overall, regardless of the chemical used. The change in chemical costs for nematode control ranges from a reduction of \$3.50 to an increase of \$33 per acre. The change in chemical costs for insect control range from a reduction of \$8.09 to an increase of \$19.50 per acre. No impacts are expected for the peanut market or final consumers.

In aggregate, the overall short-term peanut industry impact would not exceed \$4.0 million, which is the largest expected change in annual production costs. The total variable costs of production on impacted acres would increase at most 4 to 6 percent for alternative insecticides and 7 to 11 percent for alternative nematicides.

Since output is not expected to change, first-year revenue and market price effects for growers are not expected. U.S. Department of Agriculture price supports are oriented solely to peanuts intended for domestic consumer goods and can be increased by up to 6 percent a year to match aggregated estimates of regional production costs. Since only 9 percent of the U.S. peanut acreage is treated with granular carbofuran and peanuts are also marketed for oil and to foreign countries, long-term price increases are expected to be less than 1 percent.

The short term price and available quantities of consumer products are not expected to be affected by a cancellation of granular carbofuran. Longer-term price increases should be less than 1 percent.

6. Tobacco

Approximately 6 percent of all carbofuran domestic usage (both granular and flowable formulations) or 400,000 to 600,000 lb ai is used on tobacco. Overall carbofuran usage on tobacco has been declining in recent years. Approximately 100,000 to 200,000 lb ai of granular carbofuran is applied to 20,000 to 40,000 acres or 3 to 6 percent of the crop. Usage is primarily in the major tobacco-producing States of Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia.

For flue-cured tobacco, carbofuran 10G and 15G are registered for control of stunt nematodes, flea beetles, tomato and tobacco hornworms, and wireworms, and as an aid in the control of rootknot nematodes and budworms. The granular formulation is applied prior to transplanting as a broadcast soil treatment, which is incorporated to a 3-inch depth. For full-season control of flea beetles and approximately 60-day control of hornworms, the application rate is 4.0 lb ai/A and 6.0 lb ai/A for other pests. Application generally occurs from March 20 to June 10.

For varieties of tobacco other than flue-cured tobacco, carbofuran 10G and 15G is registered for control of flea beetles, hornworms, and as an aid in the control of budworms. Applications are the same as flue-cured tobacco. For full-season flea beetle control, the label rate ranges from 3.0 to 4.0 lb ai/A. For approximately 60-day control of hornworms, 4.0 lb ai/A is necessary, while 6.0 lb ai/A is used for budworms.

Carbofuran is used on tobacco primarily as an insecticide with nematocidal properties being of secondary benefit. Tobacco flea beetles and wireworms are the two most important insect pests of tobacco. Adult flea beetles damage tobacco by chewing small rounded holes in the leaves, which weaken and sometimes kill the plant, and wireworm larvae damage roots of the tobacco plant and may tunnel into the stalks. Wireworm infestations of newly transplanted tobacco can cause wilt and plant death within a few days. Adult wireworms do not damage tobacco. Registered alternatives include carbofuran 4F, chlorpyrifos, ethoprop, and others.

Tobacco and tomato hornworms can become economically important tobacco pests because of their consumption of large quantities of leaf tissue. However, with proper

scouting and adequate rescue chemicals such as carbofuran 4F and Bacillus thuringiensis, these pests should not pose a problem to growers.

Tobacco and tomato hornworms may also be reduced by eliminating crop residues by immediately plowing fields after harvest. This will reduce the overwintering population of hornworms. A braconid parasite (Apanteles congregatus) and other natural enemies aid in control of these pests. In small plantings, handpicking may be the most economical control measure. In some regions Bacillus thuringiensis has resulted in good control.

North Carolina, South Carolina, and Virginia, three of the five major flue-cured tobacco-producing States, list carbofuran in their recommendations for nematode control. The registered alternatives for the nematicidal use are ethoprop; 1,3-dichloropropene; oxamyl; and others.

Discussions with tobacco experts (U.S. Environmental Protection Agency 1987f) in the major tobacco-producing States listed above indicate that the most likely alternative to granular carbofuran is flowable carbofuran. In recent years usage has shifted from the granular to the flowable form of carbofuran. The flowable formulation has gained the major share of the market primarily because it can be easily tank-mixed with other pesticides to reduce total application costs.

Carbofuran has been field-tested as a tobacco nematicide since about 1970. The Agency reviewed efficacy and comparative performance data in the annual publications of the American Phytopathological Society's Fungicide and Nematicide Test Results for the years 1965 to 1984. From among 49 individual reports on nematicide evaluations for tobacco, 22 dealt with evaluations of carbofuran and certain alternatives for control of root-knot. Results were expressed in terms of yield (dry weight lb tobacco/A). The field tests were conducted in different regions of the country under a wide range of environmental conditions, nematode infestation levels, and cultural practices. Data for most of the test results were subjected to statistical analyses. Generally, the statistical analyses revealed that yields from nematicide treatment plots were statistically higher than yields from non-treated plots. Although there usually were marked differences in yield among chemical treatments, such differences were seldom statistically significant.

In 18 trials of direct comparison, the average yield from plots treated with carbofuran granular formulation was 2343.5 lb/A compared with 2203.4 lb/A for the nontreated controls, an increased yield of 140.1 lb for the carbofuran granular treatments.

The average yields (lb/A) in direct comparison tests from plots treated with carbofuran formulations and carbofuran alternatives are given in the following table.

<u>Alternative Tested</u>	<u>No. of Trials</u>	<u>Alternative</u>	<u>Carbofuran 10G or 15G</u>	<u>Average Yield Difference</u>
Carbofuran 4F	5	2153.6	2283.2	-129.6
Aldicarb	14	2581.3	2377.7	+203.6
Fenamiphos	6	2443.8	2395.2	+ 48.5
Ethoprop	18	2356.0	2343.5	+ 12.5
Fensulfothion	5	1847.6	1831.0	+ 16.6
Oxamyl	7	2475.0	2689.6	-214.6
1,3-dichloro-propene	7	2380.0	2129.3	+250.7

Given the limitations of comparing tests conducted under differing circumstances and the unknown effects of the insecticidal properties of the test compounds, the comparisons indicate that (1) carbofuran granular formulations are superior in performance to the flowable formulation, (2) ethoprop and fensulfothion are about equal in performance to carbofuran granulars, (3) fenamiphos may have some performance advantage over carbofuran, (4) aldicarb and 1,3-dichloropropene are superior in performance to carbofuran, and (5) granular carbofuran is superior in performance to oxamyl.

If granular carbofuran was not available to tobacco growers, it was assumed that the yields of those acres normally treated would not be significantly reduced because of the availability of some viable alternative controls. The most likely alternative to granular carbofuran for tobacco insect control is flowable carbofuran. Other alternatives include chlorpyrifos, ethoprop, fonofos, and others. No efficacy data were available for performance evaluations between these alternatives and granular carbofuran.

Nearly every tobacco specialist contacted agreed that the insecticidal uses of granular carbofuran could be replaced by the flowable with no loss in tobacco yield or quality. Although flowable carbofuran would be the primary substitute, certain pest combinations in local areas may necessitate the use of other alternatives in a minority of cases.

A change from granular to flowable carbofuran would increase per acre costs by approximately \$11 to \$20 per acre, which is less than 1 percent of annual variable production costs. A total annual production cost impact ranging from \$220,000 to \$800,000 is estimated for the current granular

carbofuran user. An average grower (5.2 acres) would have a production cost increase or annual income loss ranging from \$57 to \$104. Nonusers would not receive a windfall gain since commodity output and price effects are not anticipated. Small production cost increases (less than 1 percent) for a small proportion (3 to 6 percent) of the U.S. tobacco crop should not affect tobacco prices at the commodity or retail level; and output effects are not expected.

7. Cotton

Cotton represents less than 1 percent of the total carbofuran usage, less than 1 percent of granular usage, and less than 1 percent (about 30,000 acres, primarily in Texas) of the crop treated in the United States.

Carbofuran 10G and 15G are applied as a single at-planting, in-furrow application at 1 lb ai/A based on 40-inch row spacing for thrips control. Application generally occurs from March 1 to April 21. Insecticides applied at-planting are seldom used for thrips except as a preventive measure when the potential for damage is unusually high. Carbofuran has an 8 to 12 percent share of this market.

Thrips of several different species attack cotton. Cotton, western flower, bean, onion, and soybean thrips are the most common thrips found on cotton. Thrips overwinter as pupae in the soil. Adults emerge in early spring and build up their population on small grains and weeds adjacent to cotton fields. Cool, wet springs create stress on seedling cotton and are sometimes conducive to severe thrips injury to cotton. Thrips injurious to cotton are found throughout the cotton-growing regions of the United States. Both the larvae and adults damage cotton by rasping and sucking sap from the young leaves and pinhead squares, causing the leaves to become silvery, ragged, and curled. Heavy thrips infestations, which are unusual, will sometimes kill stands of cotton, causing plants to abort young developing squares or stunting plant growth (U.S. Environmental Protection Agency 1987f).

If plant growth is stunted by thrips infestations, the application of herbicides can be delayed. If application must be made over the top of the plant and herbicides are applied, stunting of the cotton plant from the herbicide can result. In addition thrips infestations can increase the use of herbicides for weed control because the weeds compete with the cotton for available soil nutrients. This results in large weeds and small cotton. It can also cause some growers to use unwarranted, preventive insecticidal sprays because of the ragged appearance of the cotton (U.S. Environmental Protection Agency

1987f). However, preventive control of thrips is controversial because some research indicates that this pest causes damage that reduces yield, while other research indicates it does not. Recent research has shown that thrips damage may impact yield. The estimated reduction of the 1985 national cotton yield resulting from thrips damage was approximately 0.7 percent of the annual production (Proceedings Beltwide Cotton Production Research Conference 1986).

At-planting economically viable alternatives include aldicarb, disulfoton, and phorate. Growers in Texas can substitute these alternatives and achieve satisfactory thrips control and control of other pests at no additional or average cost. If at-planting insecticides are not substituted for carbofuran, growers could apply dicrotophos, monocrotophos, dimethoate, sulprofos, disulfoton, acephate, and other registered foliar sprays when thrips appear.

In areas where wheat is grown, extension personnel recommend delaying cotton planting dates until the wheat has matured and thrips are dispersed. Scouting is also recommended to determine when thrips have reached the economic threshold level. At this threshold level, a rescue treatment is warranted (Proceedings Beltwide Cotton Production Research Conference 1986).

Two small plot studies compared carbofuran, aldicarb, and terbufos (Gallaher 1984; Lentz 1983). These studies were designed and conducted to determine the degree of thrips control achieved when soil insecticides are applied at-planting, and what the effects of their control or lack of control could have on yields. The results indicate no significant yield differences.

Alternative chemicals are available for at-planting thrips control and are generally more widely used than carbofuran. While any of the alternatives would effectively control thrips, the alternative most likely to replace carbofuran would be aldicarb. Aldicarb is currently the most widely used at-planting insecticide for thrips control and has a wider pest control spectrum than carbofuran, phorate, or disulfoton. Depending on the rate at which aldicarb is applied, the impact resulting from the substitution of aldicarb for carbofuran would vary. Actual per acre impacts are expected to range from a decrease of \$2 to an increase of \$4 in variable costs of production. Total variable cash expenses are not expected to increase by more than 3 percent without the use of carbofuran.

Any production cost increases occurring from use of aldicarb would be considerably less than 1 percent of the total value of both the U.S. and Texas cotton crops. Since

approximately 30,000 acres of cotton are treated annually with carbofuran, cancellation would result in aggregate farm level impacts totaling at most \$120,000. Adverse economic impacts are not expected to occur for either the cotton industry or other interrelated sectors of the economy from a cancellation of granular carbofuran.

8. Cranberries

The cranberry use in Washington and Oregon represents less than 1 percent of the total usage of carbofuran and less than 1 percent of the granular usage. Approximately 400 lb ai are applied to 185 acres.

Carbofuran 10G and 15G are used to control the black vine weevil in the larval stage. Carbofuran is broadcast at a rate of 2 lb ai/A over the soil surface by a rotary spreader, followed by sprinkler irrigation. Application is made between June 15 and June 25 and repeated 30 days later. Application may only be made to bogs that are not flooded for irrigation, harvest, or any other purpose. An SLN permits the use of 15G in Oregon.

Carbofuran is the only registered pesticide for black vine weevil larval control. Most adult black vine weevils are females and cannot fly. The adults are active at night and feed on cranberry leaves, which causes very little damage. They lay their eggs in the soil around the base of the plant. However, when the eggs hatch, the young larvae feed on the roots, which causes very serious damage and may kill the plant. They overwinter as partly grown larvae in earthen cells and resume feeding in the spring.

Acephate, parathion and azinphos-methyl are registered to control the adult stage of the black vine weevil. Spray applications are made at night when the adults are active and in an effort to kill the adults before eggs can be laid. Acephate is used prior to bloom. Washington recommends the use of acephate as a prebloom adulticide but not parathion or azinphos-methyl due to lack of efficacy.

Only the States of Oregon and Washington recommend the use of granular carbofuran for control of the black vine weevil on nonflooded cranberry bogs. Because of the soil terrain of these fields, these fields are not diked for flooding. Therefore, flooding, a black vine weevil control strategy, is not a viable control method.



Yield effect studies were not available. However, one small plot (Shanks et al. 1985) was examined for the comparative performance of carbofuran 10G, isofenphos 20G, bendiocarb 76WP and 2.5G, endosulfan 50WP, permethrin 3.2EC, and chlorpyrifos 4EC in controlling the black vine weevil. Carbofuran at 2.0 lb ai/A and isofenphos at 3.0 and 6.0 lb ai/A gave excellent control of the black vine weevil compared to the other treatments and control. Carbofuran-treated plots had the best vine and root vigor and fewest larvae. Larval counts in the isofenphos-treated plots were not significantly higher than the carbofuran plots. Vine and root vigor tended to be lower in the isofenphos 20G plots.

In seeking new alternatives to carbofuran use on cranberries, the Agency concentrated on the black vine weevil. Although several pesticides currently registered for other site/pest combinations could prove efficacious against the black vine weevil, the financial feasibility of registration for low volume sites precludes the Agency from making any assumptions concerning the availability of new chemical pesticides for use on cranberries.

The Agency did, however, identify what appears to be a promising biological control. Although the available data are limited to single-season trials conducted on three bogs, the data indicate that statistically significant reductions ($p = .05$) in all stages of the black vine weevil could be achieved through the application of 155 infective juveniles of the nematode Heterorhabditis heliothidis per cm² of soil (Fisher et al. unpublished). While the data do not indicate that H. heliothidis can reduce weevil populations to sub-economic levels because of the absence of threshold or yield data, the data do indicate that weevil mortality averaging 70 percent was achievable. The Agency wishes to encourage continuing research into possible applications of H. heliothidis not only in relation to cranberries, but in relation to other crops and ornamentals affected by the black vine weevil.

Due to the nature of cranberry production and the length of time the perennial crop remains in production, impacts are expected to be spread over an estimated 7-year time span. If the black vine weevil is left uncontrolled, yield losses in fields experiencing heavy infestations could be 15 percent and continue until the fields are completely destroyed (Comment #2 listed in Appendix 12).

Estimated impacts without carbofuran for black vine weevil control, and without considering the availability of acephate as an effective adulticide, are expected to occur over a 7-year time period and amount to a total of \$37,616 to \$41,616 per acre.

<u>Year</u>	<u>Type of Impact</u>	<u>Per Acre Loss (\$)</u>
1*	15% yield loss	890
2	No production -- reestablish field	10,000-14,000
3	No production	5,939
4	No production	5,939
5	1/4 of full production	4,454
6	1/2 of full production	2,970
7	3/4 of full production	1,485
8	Full production	0
Total Impact over 7-year period		37,616-41,616
<u>Present value for 7-year period</u>		<u>27,664</u>

*Year 1 is the first season without the use of carbofuran.

Taking into consideration the value of lost revenues in the future, the present value for future losses is \$27,664 per acre at a 10 percent discount rate. By annualizing the impacts, growers are expected on average to lose \$5,374 to \$5,945 per acre each year without carbofuran. Overall impacts on the 185 acres currently treated could be approximately \$7.0 million to \$7.7 million over 7 years or \$1 million to \$1.1 million annually. Without any alternatives for black vine weevil larvae control available, losses could be greater if more acres become infested. However, these losses could be over-estimated because of the availability of acephate as an adulticide.

Over the 7-year time period after which carbofuran is no longer available, localized market impacts in the form of reduced supply of cranberries in the Washington/Oregon growing regions may occur. Between 5 and 10 percent of the cranberry acreage in both States would be impacted by a cancellation of carbofuran and if acephate were unavailable. While this magnitude is not likely to affect the national supply of cranberries, it is likely that the local market would be adversely affected. It is uncertain as to whether market supplies would be reduced even further if pest infestations increased when left unchecked.

Given that localized market impacts are not expected to affect national supplies in the short run, overall consumer prices for cranberry products are not expected. It is possible, however, that consumers of cranberry products in Washington and Oregon may experience price increases in response to reduced local supplies.

9. Pineseed Orchards

Carbofuran 10G and 15G are used on pine seedlings and southern pine seed orchards to control Pales weevil,

pitch-eating weevil, Nantucket pine tip moth, pitch pine tip moth, the leaffooted and shieldback pine seedbugs, coneworms, cone borers, and cone beetles. Coneworms and seedbugs are the major pests in mature pine seed orchards, and the Nantucket pine tip moth is the major pest of concern in young pine seed orchards. Carbofuran registrations permit a single application of 0.0023 lb ai/seedling or 0.11 lb ai/A for pine seedlings based on 50 seedlings per acre, and 0.0025 to 0.050 lb ai/tree or 10.125 to 19.875 lb ai/A for pine seed orchards based on 40 trees/A.

Recent data from seed orchard managers and forest pest control specialists indicate that only 5 percent or less (100 to 500 acres) of the 10,000 acres of mature, seed-producing pine orchards in the United States are treated with granular carbofuran. The estimated total of granular carbofuran used on mature pine seed orchards is from 1500 to 7500 lb ai per year or about 1 to 7 percent of the total insecticide use. Carbofuran use is relatively important on 1- to 3-year-old seed orchards, where annual use is estimated to be less than 100 lb ai. Although carbofuran is used on a higher percentage (20 to 50 percent) of these acres, the 1500 existing base acres and application rates are lower than for mature pine seed orchards.

Fenvalerate and azinphosmethyl dominate insecticide use on mature pine seed orchards, accounting for an estimated 135,000 to 150,000 lb ai in 1986 or about 95 percent of the insecticide use on pine seedlings and pine seed orchards. Azinphosmethyl is estimated to be the single largest use pesticide at 121,500 to 135,000 lb ai or about 90 percent of the use on mature seed-producing orchards.

Some granular carbofuran is used on young orchards to protect 1- to 3-year-old plantings primarily from pine tip moth damage. This use is estimated to occur on 300 to 750 acres per year with total application of 30 to 75 lb ai per year.

Alternatives to granular carbofuran were identified as follows: carbofuran 4F, azinphosmethyl, fenvalerate, disulfoton, carbaryl, and acephate.

From limited test results and comments by orchard specialists, azinphosmethyl, fenvalerate, and permethrin appear to be effective alternatives to granular carbofuran for control of coneworms. Fenvalerate and permethrin are reportedly effective for seedbugs. No test results on pine tip moth were available, but orchard managers indicate that azinphosmethyl, acephate, and disulfoton are effective in controlling this pest.

Current insect pest management practices for pine seed orchards consist of multiple applications of fenvalerate, azinphosmethyl, and to a lesser extent, malathion.

Applications begin in late winter and are scheduled at 30- to 60-day intervals. These applications will continue into late summer. Aerial application is preferred because of better coverage, lower application rates, lower human exposure, and less drift. The timing of application is critical and is normally scheduled by using pheromone traps that monitor insect pest populations.

Experts indicate that the use of granular carbofuran on seed-producing orchards is limited and has declined significantly in recent years. The one major use still cited is for tip moth control on young grafted seedlings in the first 2 to 3 years of an orchard establishment.

Without carbofuran, it is anticipated that one treatment of fenvalerate followed by 1 to 2 treatments of azinphosmethyl would be the likely substitute. Control using the alternatives would average about the same as granular carbofuran. Depending on whether 1 treatment with fenvalerate followed by 1 to 2 treatments with azinphosmethyl are made, impacts could range from -\$37 to +\$22 per acre. At the high impact level, costs would increase by \$22 per acre per year. Given normal operating and maintenance costs for an orchard at \$750 to \$900 per acre per year, costs at maximum would increase 2 to 3 percent per year, but also could decrease by 4 to 5 percent.

Using the range of per acre cost changes, order-of-magnitude aggregate cost impacts can be estimated. Assuming 500 acres of pine seed orchards are treated annually with granular carbofuran, the range of aggregate impact is -\$18,500 to +\$11,000. This impact is relatively small in comparison to the annual economic value of seeds potentially produced from 10,000 acres at 40 lb/A valued at \$500 per pound or \$200 million. It is also small relative to the hypothetical market value seeds assuming \$60 per pound or \$24 million.

10. Sunflowers

The use of carbofuran on sunflowers represents 2 percent of annual usage and less than 1 percent of granular usage. Approximately 18,400 to 121,100 lb ai are used to treat 18,400 to 105,900 acres.

Carbofuran 15G is used in North and South Dakota to control the sunflower stem weevil; the sunflower beetle; and migratory, redlegged, two-striped, differential, and clearwinged grasshoppers. Use at planting may be made either as in-furrow or 7-inch band application. Application is 2.3 to 2.6 lb ai/A with 30-inch row spacing. In-furrow application is made by directing the granules into the planter shoe with the seed or by placing the applicator tube directly behind the planter shoe so that granules drop into the furrow and mix with the covering soil. Band application is followed by mixing the granules with the covering soil. Application is generally made May 1 to May 30.

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Adult sunflower stem weevils emerge in mid-June and feed on the epidermal tissue of the sunflower foliage and upper stem. Although feeding causes only minor damage, these pests are vectors of Rhoma oleracea, which cause black stem disease in sunflowers. These adults deposit eggs in the epidermal tissue of the sunflower stem. Upon hatching, the first instar larvae feed on subepidermal and vascular tissues. As the larvae further develop, they feed mainly in the pith tissue. When larval infestations reach 25 to 30 or more per stalk, the stem tissue weakens and breakage may occur, especially when plants are under stress from drought or wind.

Scouting for sunflower stem weevils is recommended when plants are at the 8- to 14-leaf stage. The economic threshold is two adults per plant. (The economic threshold is the number of pests or the resulting pest damage that a crop can tolerate before an economic loss or yield reduction occurs.) In heavily infested fields, fall plowing helps reduce weevil populations.

The sunflower beetle is a pest in the Northern Plains of the United States. Adults overwinter in the soil and begin feeding soon after emergence. The first leaves of the sunflower may be severely damaged or completely consumed. Depending on the number of beetles, fields may be defoliated. These adults lay their eggs on the stems and undersides of leaves. The newly hatched larvae chew holes in the sunflower leaves and may defoliate a plant.

Scouting for adult sunflower beetles is recommended to determine if economic thresholds have been reached. Control is recommended if defoliation reaches 25 to 30 percent. If the majority of the larvae have reached maturity at this level of damage, control is not warranted.

Grasshopper adults and nymphs damage sunflowers by defoliating plants.

Carbofuran 4F is the only registered at-planting alternative to the granular formulation. However, chlorpyrifos, carbaryl, methidathion, methyl or ethyl parathion, and fenvalerate are registered for rescue treatment and are equally effective. Based on several small plot studies comparing the performance of granular carbofuran, aldicarb, and terbufos and the foliar sprays of carbofuran 4F, cyfluthrin, fenvalerate, methidathion, and permethrin, no significant yield differences resulted (U.S. Environmental Protection Agency 1987f).

North Dakota has been the major State using granular carbofuran in preventive treatment programs; however, depressed economic conditions in the sunflower markets as a

result of high food oil supplies, have resulted in trend decreases in granular carbofuran use in North Dakota and all other sunflower-producing areas.

Cancelling granular carbofuran on sunflowers will have a relatively small impact upon the remaining users of granular carbofuran. First, many producers are shifting to rescue treatment programs that are currently more cost effective. Several alternatives are available, though more than one material may be needed. Second, flowable carbofuran will remain as a registered preventive treatment insecticide. The costs of retrofitting planter equipment to apply liquids do not appear generally prohibitive and range from \$500 to \$1000 for a 6-row planter. This can be amortized over approximately 3 years.

No significant economic impacts are expected because production levels should remain relatively constant and costs of production should not increase. In some years, production costs will likely be lower using rescue treatment programs. Consumers should not be affected.

C. Analysis of Rebuttal Comments

The Agency received eight public comments related to the benefits of granular carbofuran use. These comments and the Agency's responses are discussed below.

1. Comment: Washington State University Cooperative Extension Service (Comments #1 and #2) provided use information on treating nonflooded cranberry bogs with carbofuran to control root weevils, a pest for which there are no other registered pesticide alternatives.

Response: The Agency has evaluated and incorporated the benefits data submitted regarding cranberries in its benefits analysis. The data included acreage treated, lb ai applied, pest data, and economic impacts.

2. Comment: Abbott Laboratories' rebuttal identified their product Dipel, Bacillus thuringiensis, as a potential alternative for control of the European corn borer on corn.

Response: Its potential as an alternative was considered by the Agency and is mentioned in Section B.1. of this chapter.

3. Comment: The Rice Research Board (Comments #5 and #13), FMC Corporation (Comment #7), and the University of California (Comment #11) submitted information on the benefits of using carbofuran for rice water weevil control.

Response: The use and usage information contained in these rebuttals were considered in the preparation of the benefit analysis.

4. Comment: FMC Corporation provided additional information on other crops. This information included field corn data providing comparisons of carbofuran, terbufos, phorate, trimethacarb, fonofos, and ethoprop in controlling corn rootworm larvae with measurements based on an average root rating system.

Response: The Agency used this information in the biological and economic analysis for carbofuran. This analysis is discussed in Section B.1. of this chapter.

Data indicated that carbofuran was better than terbufos and phorate in regions where these pests are major problems. The in-furrow application was preferred because it allowed for faster chemical uptake by the plant and more rapid systemic activity for pest control. Also, information was presented that indicated aldicarb was more effective than carbofuran in reducing nematode populations. Yield effects were not provided in any studies.

5. Comment: FMC's rebuttal cited nematocidal benefits for applications to field corn related to reduced pest populations and yield increases.

Response: Separate yield increases from nematode control cannot be separated from insect control.

6. Comment: FMC presented data demonstrating the efficacy of granular carbofuran compared with the flowable formulation.

Response: The majority of the efficacy studies submitted by FMC were based on the 10G and 15G formulations for the control of the corn rootworm complex. A review of the yield data from those studies in which the flowable formulation was used indicate that the yields were comparable to those plots treated with the granular formulations. Therefore, EPA considered the flowable formulation is comparable in efficacy to the granular formulation.

7. Comment: FMC commented that flowable carbofuran applied at planting is as effective as an at-planting granular treatment, but that the growers equipped to use a liquid at planting insecticide are limited.

FMC indicated that the change would result in added cost to growers and that the hazards involved in handling more toxic liquid formulations make this change undesirable.

Response: The Agency recognizes that the flowable may not be acceptable to certain growers who do not have the proper application equipment. However, granular alternatives are available for most carbofuran use sites. The Agency anticipates that growers will substitute these granular alternatives. The human hazard from these alternatives is evaluated in Chapter IV.

8. Comment: FMC submitted information on sorghum related to the use of granular carbofuran as a control of greenbug and chinch bug.

Response: The information was incorporated into the benefits analysis.

9. Comment: FMC developed quantitative economic benefits to users, society, and the environment from the use of carbofuran on corn, sorghum, rice, and sunflowers. FMC estimated the benefit from carbofuran granules to be \$250 million annually on all four sites. This estimate was determined by using the average yield increase from use of carbofuran over untreated check plots.

Response: The Agency does not agree that the economic benefits from carbofuran on corn, rice, sorghum, and sunflowers is \$250 million. The Agency conducted benefit analyses and determined the economic impacts based on a substitute chemical/control method approach. Rather than implying that without a particular chemical a grower will do nothing to control a pest, the Agency determines what other control methods are available, and the likelihood that they could effectively replace carbofuran. Impacts are then determined by the differences (e.g., chemical costs, application costs, yield losses, etc.) between the chemical under Special Review and the alternatives. Benefits are better determined by this method than by comparing the higher yields and quality of commodities from the use of chemical to the output of an untreated field.

10. Comment: The U.S. Forest Service (Comment #8) provided use and usage information on carbofuran for pest control in pine seed orchards.

Response: The information was considered by the Agency in its analysis and used as appropriate.

D. Additional Public Comments

In addition, FMC Corporation submitted comments on a draft of the Agency's "Biological Chapters for Preliminary Benefit Analyses of Carbofuran" (U.S. Environmental Protection Agency 1986a). Their comments and the Agency's responses are as follows:

1. Comment: The Agency did not consider that most crops are subject to a variety of pests, depending on the geographic location of a crop. Thus, evaluating alternatives on an individual pest basis is not appropriate.

Response: The Agency recognizes that most growers face a variety of pests. The Agency is also aware of the variation in pest control problems in different geographic locations. The benefits analysis addresses the major pests of concern for which growers use carbofuran as a control.

2. Comment: EPA indicated several flowable products as potential substitutes for granular carbofuran. Depending on the cultural practices of a particular area, a change from a granular to a flowable may not be acceptable to a grower.

Response: The Agency recognizes that some of the alternatives addressed in the benefits assessment may not be suitable to every grower's needs. EPA is not suggesting that growers change their cultural practices, nor is EPA suggesting that growers use a particular alternative. EPA is only identifying those alternatives that demonstrate efficacy against certain pests.

3. Comment: The Agency did not consider the economic benefits associated with carbofuran in the biological assessment.

Response: The Agency evaluated the economic benefits in a separate document. A summary of the economic benefits is contained in this chapter as a part of the discussion of each of the major use sites.

4. Comment: The Agency did not consider human or nontarget exposure of carbofuran and its alternatives in the biological assessment.

Response: The Agency has evaluated such exposure in Chapters II and IV of this document.

5. Comment: The Agency has not addressed the importance of crop rotation between organophosphate and carbamate pesticides. Eliminating carbofuran would leave only one carbamate available for crop rotation.

Response: The Agency has indicated in its benefits assessment that carbofuran is rotated with organophosphate insecticides to help prevent pest resistance and that this may be one of the benefits of its continued use. However, the Agency is also aware that there may be some potential for organophosphate and carbamate cross-resistance.

6. Comment: Carbofuran provides systemic control of stem weevils in sunflowers. No alternative is available.

Response: The Agency recognizes that no granular alternatives for control of the stem weevil are available. However, the flowable carbofuran formulation is available as an alternative and is effective according to FMC Corporation (Comment #7 submitted in response to PD 1).

7. Comment: Carbofuran provides systemic control of cucumber beetle in cucurbits. No alternative is available.

Response: Ten States including Delaware, Illinois, Maryland, Michigan, Missouri, New Jersey, Ohio, Pennsylvania, and Virginia have SLN registrations that permit granular carbofuran to be applied at planting for control of cucumber beetles on cucurbits. This application reduces the need for later foliar sprays such as carbaryl, azinphosmethyl, methomyl, methoxychlor, and fenvalerate.

8. Comment: Carbofuran provides systemic control of first-generation European corn borers and green peach aphids in peppers. No alternatives exist.

Response: Though there may not be systemic alternatives that will give simultaneous control of both the European corn borer and the green peach aphid, there are foliar alternatives such as azinphosmethyl, methomyl, acephate, permethrin, and fenvalerate for control of the European corn borer. For control of the green peach aphid, dimethoate, oxydemeton-methyl, methomyl, acephate, mevinphos, and phorate could be considered.

9. Comment: Carbofuran controls root weevils in cranberries. No alternatives are available.

Response: The Agency recognizes that no alternatives are registered for its control.

10. Comment: Carbofuran provides control for the Colorado potato beetle and nematodes in potatoes. Aldicarb is the only alternative and is considered more expensive.

Response: For control of the Colorado beetle on potatoes the following foliar alternatives are available: carbofuran flowable, azinphosmethyl, phosmet, permethrin, fenvalerate, rotenone, and oxamyl. The registration for nematode control is covered by a Florida SLN registration and the alternatives would be oxamyl and soil-applied fumigants.

E. Conclusions

Approximately 7 to 10 million lb ai of all carbofuran formulations are used on a variety of agricultural crops and forestry sites per year and approximately 6 to 9 million lb ai of the granular formulation. The percentage of granular carbofuran use on the 10 major crops is as follows: 68 percent on field corn, 14 percent on sorghum, 5 percent on soybeans, 2 percent on rice, 5 percent on peanuts, and 2 percent on tobacco. Also, less than 1 percent is used on each of the following crops: cotton, cranberries, sunflowers, and pine seed orchards. These uses encompass over 95 percent of the granular carbofuran usage and 85 percent of all carbofuran formulation usage.

If carbofuran is not available for treatment of the 10 crops, the Agency estimated an annual grower impact that ranged from \$22.8 to \$33.0 million. The largest economic impact from cancellation of granular carbofuran will be on rice since no registered alternatives are available for control of the rice water weevil. The Agency estimated a grower impact of \$12.2 million annually; a \$6.1 million decrease in Federal deficiency payments to rice growers would indicate an efficiency loss of \$6.1 million.

Field corn is the major use site for carbofuran, and cost-effective, efficacious alternatives are available. No changes in costs of production, yields, or revenues are expected. The corn insecticide market is highly competitive, and viable alternatives are available with similar product performance and at comparable cost per acre.

The carbofuran market for field corn has been declining since 1978 and current usage is approximately one-third the level it was in 1978. Carbofuran has lost its market share, primarily to terbufos and chlopyrifos. By 1986 the market share held by carbofuran dropped to less than 15 percent, where in terms of acre treatments it ranked fourth out of the five major field corn insecticides. The reasons for this decline are not clear, but could include loss of efficacy and spectrum of control.

Carbofuran is applied to an estimated 185 acres of nonflooded cranberries in Washington and Oregon to control the black vine weevil larvae. Because of the soil or the terrain of the fields, these cranberry acres are not diked for flooding. While carbofuran is the only pesticide registered for control of the black vine weevil larvae, acephate is an efficacious pesticide for the adult stage. The impact on cranberries, without considering acephate's use, is expected to occur over a 7-year period due to the perennial nature of the crop. Overall impacts could be approximately \$7 million to \$7.7 million over the 7 years or \$1 to \$1.1 million annually.

For the U.S. sorghum industry, cancellation would generally not have an adverse effect on the overall sorghum industry (\$0.4 to \$0.9 million annually at most) or consumers. In years of high chinch bug infestations, which occur every 5 to 10 years, annual income reduction could range from \$7.4 to \$9.3 million if aldicarb is used as an at-planting alternative; eastern Kansas is a localized area expected to experience the most adverse impact. However, this impact does not consider the foliar treatments that are available for use when infestations actually occur. Foliar treatments may not always provide adequate control because of problems with treatment timing, limited availability of scouts, and chinch bug reinfestations.

For the remaining crops, the Agency does not anticipate major impacts from cancellation or unavailability of carbofuran. The overall economic impact from cancellation on the remaining is expected to be nominal, with no significant changes in either production costs or outputs.

The Agency also evaluated aspects of carbofuran use that are not easily quantifiable. For example, only one carbamate (trimethacarb) would be available for field corn growers who rotate organophosphate and carbamate insecticides to delay resistance in soil pests, although the Agency recognizes that some cross-resistance with organophosphates could occur. Also, carbofuran has residual and systemic properties and a broad spectrum of control. However, repeated use of carbofuran may lead to an apparent increase in soil microbial populations, which are capable of reducing its effectiveness.

IV. HUMAN RISKS FROM CARBOFURAN AND ITS ALTERNATIVES

The Agency evaluated the toxicity to humans from carbofuran and some of its alternatives, as well as the potential for ground water contamination.

A. Human Toxicity of Carbofuran and Its Major Alternatives

The Agency evaluated the toxicological data from the FFA registration files on carbofuran and some of its alternatives (U.S. Environmental Protection Agency 1987a). EPA evaluates the scientific reliability of data and assigns different categories of appraisal. Studies graded as Core-Minimum or Core-Guideline are acceptable studies and may be used to support the registration of a product. A Core-Supplementary study contains some useful information but is incomplete. A study that was not core-graded is unacceptable. Neither a Core-Supplementary nor a study indicated as not core-graded can be used to support a registration.

1. Carbofuran

Carbofuran has acute toxic effects, including lethality resulting from the rapid inhibition of acetylcholinesterase activity. Acute oral LD50 values in mammals are reported as 2.0 mg/kg/day in mice and 6.4 to 14.1 mg/kg in rats. In dogs, 20 percent lethality was observed at a dosage level of 18.85 mg/kg.

In rats fed carbofuran at dosage levels of 1.0, 2.9, 5.8, 7.7, or 9.7 mg/kg/day or at 1, 3, or 8 mg/kg/day on days 6 through 19 of gestation, no observed clinical signs of toxicity or adverse effects on pup survival or visceral or skeletal development were observed. Maternal body weight gains were reduced at the 2.9 to 9.7 mg/kg/day dosage levels in the first study and in the 3 and 8 mg/kg/day dosage groups in the second study. A no-observable-effect level (NOEL) of 1.0 mg/kg/day resulted.

When rabbits were administered carbofuran at 0.12, 0.5, or 2.0 mg/kg/day by gavage on days 6 to 18 of gestation, no terata was observed in the offspring. Also, no decreases in the number of fetuses or litters or observable developmental or genetic abnormalities resulted. Dams at the highest dosage level experienced a 20 percent reduction in weight gain during the treatment period.

Carbofuran was also administered orally to healthy human males at two subjects per dose level. No symptoms were observed at 0.05 mg/kg. At 0.10 mg/kg, symptoms included headache and, possibly, lightheadedness; at 0.25 mg/kg, symptoms of acetylcholinesterase depression were observed, including salivation, diaphoresis, abdominal pain, drowsiness, dizziness, anxiety, and vomiting. The 0.05 mg/kg dose level was defined as the NOEL in this study.

In a 3-generation study in which rats were fed carbofuran at 1.0 or 5.0 mg/kg/day, no adverse effects were observed on female or male fertility, length of gestation, litter size or growth, or pup viability. At the high dose, however, the survival of the first litter in all three generations was slightly lower by day 4 of lactation. The NOEL for reproductive effects was determined to be 1.0 mg/kg/day.

In a 2-year study, rats were administered carbofuran in the diet at dosage levels of 0, 0.5, 1.0, or 5 mg/kg/day. No adverse effects were observed on body weight, food consumption, behavior, ophthalmoscopy, hematology, biochemistry, urinalysis, or histopathology. At the highest dosage, slight decreases in mean body weight were observed in males. An inhibition of plasma, RCB, and brain cholinesterase levels in both sexes also resulted. The NOEL for this study was determined to be 1.0 mg/kg/day.

In a similar 2-year study in mice, dietary administration of carbofuran at dosage levels of 3, 18.8, or 75 mg/kg/day resulted in no observed adverse effects on food consumption, behavior, hematology, biochemistry, urinalysis, or histopathology. At the highest dose, a temporary decrease in body weight resulted. At the two highest doses, reductions in brain cholinesterase levels were observed. This study defines a NOEL of 3 mg/kg/day.

In a 1-year feeding study in beagle dogs, no biologically important adverse effects on various biochemical, hematological, or clinical parameters at 0.25 or 0.50 mg/kg/day were reported. At 12.5 mg/kg/day, there was marked depression of plasma and erythrocyte cholinesterase levels in both sexes, testicular degeneration and some aspermia in males, and uterine hyperplasia and hydrometria in females. A NOEL of 0.50 mg/kg/day was identified for dogs based on the results of this study.

A 2-year dietary study in rats at dosage levels of 0.5, 1.0, or 5 mg/kg/day revealed no evidence of carcinogenicity.

A 2-year dietary study in which mice were administered carbofuran at dosage levels of 3, 18.8, or 75 mg/kg/day revealed no evidence of carcinogenicity.

Ames bacterial test results were negative except in one of six studies, in which carbofuran was applied at up to 10 ug/ plate with rat liver S-9 activation. Carbofuran was mutagenic in Salmonella typhimurium strains TA98 and TA1538.

Results of mutagenicity tests of carbofuran in each of several other test organisms were negative except for CHO V79 cells. These cells were reported positive at an unspecified dosage of carbofuran without, but not with, rat liver S-9 activation.

The carbofuran data base is acceptable and is considered complete.

2. Trimethacarb

The acute oral LD50 in rats is 178 with 95 percent confidence intervals of 150 to 211 mg/kg. Delayed neurotoxicity in the hen was negative up to 200 mg/kg.

Teratogenic evaluation in Fischer rats at 0, 7.5, 15, and 30 mg/kg/day demonstrated a negative teratogenic potential at 30 mg/kg/day of the highest dose tested (HDT). The fetotoxic NOEL was also 30 mg/kg/day. The maternal NOEL was 7.5 mg/kg/day and at the maternal lowest effect level (LEL) of 15 mg/kg/day, clinical signs and reduced body weight and food consumption were observed. The study was Core-Supplementary.

Teratogenic evaluation in New Zealand White rabbits at 0, 12.5, 25, and 50 mg/kg/day resulted in a maternal NOEL of 25 mg/kg/day. At the maternal LEL of 50 mg/kg/day mortality, clinical signs and reduced body weight gain were observed. The fetotoxic and teratogenic potential could not be determined with available data. The study was Core-Supplementary.

In a 3-generation rat reproduction study performed in 1968 at dosages of 0, 50, 200, and 800 ppm, the reproductive NOEL was 800 ppm (HDT). The systemic NOEL was 200 ppm, and the LEL was 800 ppm. There were elevated spleen weights in females. The study was not core-graded.

In a 2-year feeding study in dogs at dosages of 0, 100, 500, 1250, and 2500 ppm, the 2500 ppm dose group was terminated at 7 months due to severe weight loss. Inhibition of brain cholinesterase was observed in the 2500 ppm group. The systemic NOEL for the study was 500 ppm. At the LEL of 1250 ppm, growth depression was observed. The study was not core-graded.

In a 2-year rat feeding study performed at dosages of 0, 12.5, 50, 200, and 800 ppm, a systemic NOEL of 50 ppm was established. At the LEL of 200 ppm, 10 to 20 percent of brain

cholinesterase was observed. At 800 ppm, there was acute or subacute gastritis, slight increase in spontaneous kidney disease in females, and fatty metamorphosis of the liver, which disappeared after 7 1/2 months. The study was not core-graded.

The mutagenic and oncogenic potential of trimethacarb have not been evaluated.

3. Ethoprop

The acute oral LD50 in rats is 56.2 (45.3 to 69.9) uL/kg for males and 30.2 (23.4 to 38.9) uL/kg for females. Signs of inhibition of acetylcholinesterase were observed in animals dosed at 21.5 uL/kg and higher. The study was not core-graded.

Acute delayed neurotoxicity in hens was negative at 11.70 mg/kg and 13.25 mg/kg. The study was Core-Minimum.

Teratogenic evaluation was conducted at dosages of 0, 0.16, 1.6, and 16.0 mg/kg in Sprague-Dawley rats. The teratogenic potential was negative up to 16 mg/kg (HDT). The maternal NOEL was 1.6 mg/kg. At the maternal LEL of 16 mg/kg, increased mortality was observed. At the lowest dose tested (LDT) (0.16 mg/kg), possible embryotoxicity was evidenced as incomplete ossification of vertebrae. However, this effect was not dose-related. The study was classified as Core-Minimum.

A 90-day rat feeding study was performed at doses of 0, 0.3, 1.0, and 100 ppm. A systemic NOEL of 0.3 ppm (LDT) was established. At the systemic LEL of 1.0 ppm, there was inhibition of body weight gain. The cholinesterase NOEL was also 0.3 ppm. The study was not core-graded.

A 13-week dog feeding study was conducted at doses of 0, 1, 3, and 100 ppm. The systemic NOEL was 100 ppm (HDT). The acetylcholinesterase inhibition NOEL was 1.0 ppm (LDT). The study was Core-Minimum.

Ethoprop was not mutagenic at doses up to and including 5 ug/L/plate (HDT) in Salmonella typhimurium strains TA1535, TA1537, TA1538, TA98, TA100, and Saccharomyces cerevisiae, strain D4, both with and without metabolic activation. The study was not core-graded.

Additional mutagenic and oncogenic evaluations have not been performed.

4. Chlorpyrifos

The acute oral LD50 is 163 mg/kg in male rats and 137 mg/kg in female rats.

The teratogenic potential in mice is negative at dosages up to 25 mg/kg/day. The fetotoxic NOEL is 10 mg/kg and at the LEL of 25 mg/kg. Decreased fetal length and increased skeletal variants were observed. The NOEL for plasma and RBC cholinesterase inhibition is 0.1 mg/kg/day. The study was Core-Minimum.

Teratogenic evaluation in rats at dosages of 0, 0.1, 3.0, and 15 mg/kg showed no teratogenic potential at 15 mg/kg (HDT). The fetotoxic NOEL is also 15 mg/kg. The maternal NOEL is 0.1 mg/kg with cholinesterase inhibition observed at the LEL of 3.0 mg/kg. The study was Core-Minimum.

The 3-generation rat reproduction study had a reproductive NOEL of 1.0 mg/kg/day (HDT). The doses evaluated were 0, 0.03, 0.1, and 1.0 mg/kg/day. The study was Core-Minimum.

A 2-generation rat reproduction study had a reproductive NOEL of 1.2 mg/kg/day. The systemic NOEL was 0.8 mg/kg/day and at the systemic LEL of 1.2 mg/kg/day, decreased weight gain was observed. The levels tested were 0, 0.5, 0.8, and 1.2 mg/kg/day in Sprague-Dawley rats. The study was Core-Supplementary.

A 2-year dog feeding study at doses of 0, 0.01, 0.03, 0.10, 1.0, and 3.0 mg/kg/day had a systemic NOEL of 1.0 mg/kg/day. At the systemic LEL of 3.0 mg/kg/day increased liver weight was observed. The cholinesterase inhibition NOELs were 0.01, 0.10, and 1.0 mg/kg/day for plasma, RBC, and brain, respectively. The study was Core-Minimum.

A 2-year rat feeding study at doses of 0, 0.01, 0.03, 0.10, 1.0, and 3.0 mg/kg/day was classified as Supplementary due to insufficient numbers of animals and tissues at final sacrifice. A valid assessment of chronic or oncogenic effects could not be made. The cholinesterase inhibition NOEL was 0.10 mg/kg/day.

A 2-year oncogenic study in mice at doses of 0, 0.5, 5.0, and 15.0 ppm revealed a negative oncogenic potential of 15 ppm (HDT). The study was Core-Minimum.

Acute delayed neurotoxicity in hens was negative at 50 and 100 mg/kg. The study was Core-Minimum.

Acceptable mutagenic studies were reported for bacterial DNA repair (positive), mitotic recombination in *S. cerevisiae* (weakly positive), mouse micronucleus (negative), Chinese hamster ovary (negative), rat hepatocyte UDS (negative), and Salmonella/microsome assay (negative). Several unacceptable mutagenicity studies were performed.

5. Fonofos

The acute oral LD50 is 10.8 (7.4 to 15.7) mg/kg in male rats and 5.8 (3.6 to 9.5) mg/kg in female rats.

Three chicken studies were available to evaluate acute delayed neurotoxicity. In the first study, a NOEL of 6.32 mg/kg was established. At the LEL of 20 mg/kg, slow loco-

motion, curling under of toes, head lowering, squatting, loss of equilibrium, and possible demyelination of peripheral nerve in one chicken were observed. The study was Core-Minimum.

In a second study, an intramuscular LD50 dose of 50 mg/kg produced ataxia, pupillary constriction, and gulping.

These toxic signs were less severe when pretreated with 2 mg/kg atropine and 50 mg/kg 2-PAM. The study was Core-Supplementary.

In a third study, feeding chickens for 46 days at 20 mg/kg/day produced delayed neurotoxicity signs at week 4. The study was Core-Supplementary.

The teratogenic potential in mice was negative at 8 mg/kg/day (HDT) in a study in which CD-1 mice were gavaged with 0, 2, 4, 6, and 8 mg/kg/day. The maternal NOEL was 6 mg/kg/day. At the LEL of 8 mg/kg/day, some symptoms of neurotoxicity, including tremors, chromodacryorrhea, and dacryorrhea were observed.

The fetotoxic NOEL was 2 mg/kg/day and at the LEL of 6 mg/kg/day sternebral malalignment and slight dilation of the fourth ventricle was observed. The study was Core-Minimum.

A 3-generation rat reproduction study at doses of 0, 10, and 31.6 ppm showed a reproductive NOEL of 31.6 ppm (HDT). The study was not core-graded.

A 2-year rat feeding study at doses of 0, 10, 31.6, and 100 ppm had a systemic NOEL of 31.6 ppm. At 100 ppm, tremors and nervous behavior were observed. A cholinesterase inhibition NOEL was not established, since brain cholinesterase activity was depressed at 10 ppm. The study was Core-Supplementary.

A 2-year dog feeding study at doses of 0, 8, 60, and 240 ppm established a systemic NOEL of 8 ppm. At the systemic LEL of 60 ppm, increased liver weight, microscopic findings in the liver and small intestine, tremors, lacrimation, and salivation were observed. The study was not core-graded. Fonofos was not mutagenic in six assays (five in microorganisms and one in human cells) either with or without metabolic activation.

The oncogenic potential has not been examined. It should be noted that, from the data, fonofos may be a delayed neurotoxic agent.

6. Phorate

The acute oral LD50 in male rats is 2.71 (2.00 to 3.69) mg/kg.

Phorate was negative for acute delayed neurotoxicity. The study was Core-Minimum.

The teratogenic potential was negative in rats at doses up to 0.5 mg/kg (HDT). The levels tested by gavage in Sprague-Dawley rats were 0, 0.125, 0.25, and 0.50 mg/kg/day. The maternal and fetotoxic NOEL was 0.25 mg/kg/day and at the fetotoxic LEL of 0.50 mg/kg/day, enlarged hearts were observed. The study was Core-Guideline.

A 3-generation mouse reproduction study at doses of 0, 1.5, and 3.0 ppm had a reproductive NOEL of 1.5 ppm. At the reproductive LEL of 3.0 ppm, decreased lactation index and viability index were observed. The study was not core-graded.

A 2-year rat feeding/oncogenic study at doses of 0, 1, 3, and 6 ppm was negative for oncogenicity at 6 ppm (HDT). A NOEL of cholinesterase inhibition was not established since plasma cholinesterase was inhibited at 1 ppm. The study was graded as Minimum for oncogenicity and Supplementary for chronic toxicity.

An 18-month mouse oncogenicity feeding study was negative for oncogenic potential at 6 ppm (HDT). The doses tested were 0, 1, 3, and 6 ppm. The study was Core-Minimum.

A rabbit teratology study at doses of 0, 0.3, 0.6, and 0.9 mg/kg/day was invalid because sick animals were used.

A bone marrow cytogenetic mutagenicity assay was negative and was acceptable. Other mutagenicity studies were not performed.

7. Diazinon

The acute oral LD50 is 108 (96 to 122) mg/kg for male rats and 76 (66 to 87) mg/kg for female rats.

The teratogenic potential in New Zealand White rabbits was negative at 100 mg/kg (HDT) where doses of 0, 7.0, 25.0, and 100 mg/kg/day were evaluated. The maternal NOEL was 25 mg/kg. At the LEL of 100 mg/kg, increased mortality was observed. The fetotoxic NOEL was 100 mg/kg (HDT). The study was Core-Minimum.

IV-7

The teratogenic potential in Sprague-Dawley rats was negative at 100 mg/kg (HDT) where doses of 0, 10, 20, and 100 mg/kg/day were employed. The fetotoxic NOEL was 100 mg/kg (HDT). The maternal NOEL was 20 mg/kg and at the maternal LEL of 100 mg/kg, decreased food consumption, body weight, and body weight gain were observed. The study was Core-Guideline.

Delayed neurotoxicity in hens fed diazinon at doses up to and including 200 ppm for 22 days was negative. The study was Core-Supplementary.

A 3-generation rat reproduction study at doses of 0, 4, and 8 ppm had a reproductive NOEL of 4 ppm (only dose tested) for 3 generations and a reproductive NOEL of 8 ppm (two doses tested) for 2 generations. The study was Core-Supplementary.

Oncogenic potentials in mice and rats were negative in Core-Minimum studies. In the mouse study, the oncogenic potential was negative up to 200 ppm (HDT).

The oncogenic potential in the rat was negative up to 800 ppm (HDT). The chronic toxicity aspects were Core-Supplementary. The mutagenic potential was negative in Ames assay, reverse mutation in *E. coli*, mitotic recombination in *S. cerevisiae*, DNA repair in *E. coli*, DNA repair in *B. subtilis*, and unscheduled DNA synthesis. These mutagenic studies were acceptable. Other mutagenicity studies were unacceptable.

8. Terbufos

The acute oral LD50 is 4.5 (2.6 to 7.7) mg/kg in male rats and 9.0 (5.2 to 15.3) mg/kg in female rats.

The acute delayed neurotoxicity potential is negative at 40 mg/kg (only dose tested). The study was Core-Minimum.

The teratogenic potential has not been evaluated in an acceptable study.

A 3-generation rat reproduction study was performed at doses of 0, 0.25, and 1.0 ppm. The reproductive NOEL was 0.25 ppm. At the LEL of 1.0 ppm, an increased percentage of litters with dead offspring in each of the 3 generations in comparison with controls resulted. The study was Core-Minimum.

A 6-month dog feeding study at doses of 0, 0.0025, 0.01, and 0.04 mg/kg/day showed a systemic NOEL of 0.04 mg/kg/day (HDT) and a cholinesterase inhibition NOEL of 0.0025 mg/kg/day. The cholinesterase inhibition LEL was 0.01 mg/kg/day and decreases in plasma and RBC levels were observed. The study was Core-Supplementary.

The oncogenic potential in mice was evaluated in an 18-month study at doses of 0, 0.5, 2.0, and 8.0 ppm. The oncogenic potential was negative at doses greater than 8.0 ppm (HDT). The study was Core-Supplementary.

The oncogenic potential in rats was evaluated in a 2-year rat feeding/oncogenic study at doses of 0, 0.25, 1.0, and 2.0 ppm. The oncogenic potential was negative at 2.0 ppm (HDT) and was Core-Minimum. The systemic NOEL and choline-terase inhibition NOEL were not established since effects were observed at 0.25 ppm (LDT). The study was Supplementary for chronic toxicity.

The mutagenic potential was negative in several acceptable studies, including the Ames assay, DNA repair, chromosome aberration in Chinese hamster cells, mammalian cell mutation (HGPRT), and rat hepatocyte primary culture/DNA repair.

9. Aldicarb

The acute oral LD50 in rats is 0.9 mg/kg.

The teratogenic potential in Dutch Belted rabbits was negative at doses of 0.1, 0.25 and 0.50 mg/kg/day. The fetotoxic NOEL was less than 0.1 mg/kg/day (LDT). At this dose and greater, the effects observed were a decreased number of viable fetuses and implantations per doe. In this study, the maternal toxic NOEL was established at 0.25 mg/kg/day. At the LEL of 0.5 mg/kg/day, the rabbits exhibited decreased body weight, pale kidneys and hydroceles on the oviducts. The study was classified as core-guideline.

In a rat teratology study, the teratogenic potential was negative up to 1.0 mg/kg/day (HDT). The study was classified as core-minimum.

In a 3-generation rat reproduction study, the maternal reproductive NOEL was 0.7 mg/kg/day (HDT). Decreased body weight in fetuses was observed at 0.7 mg/kg/day with the fetotoxic NOEL for this effect established at 0.3 mg/kg/day. The study was classified as core-minimum.

A 90-day rat feeding study at dosages of 0.02, 0.1, and 0.5 mg/kg/day had a NOEL of 0.1 mg/kg/day. At the LEL of 0.5 mg/kg/day, the rats had decreased body weight. The study was core-minimum.

A 90-day dog oral study at doses of 0.2, 0.3 and 0.7 mg/kg/day had a NOEL of 0.3 mg/kg/day. At the LEL of 0.7 mg/kg/day, there were decreased testes weights and increased adrenal weights in males. The study was core-minimum.

In a 2-year dog oral study at doses of 0.025, 0.05 and 0.1 mg/kg/day, the NOEL was established at 0.1 mg/kg/day (HDT). The study was core-minimum.

In a 2-year rat feeding study at 0.3 mg/kg/day (only level tested), there were no compound-related differences from controls in mortality, growth, hematology, histologic abnormalities and tumors. The study was core-minimum.

Another 2-year rat feeding study at 2 and 6 ppm did not show any carcinogenic potential up to 6 ppm (HDT). The study was core-minimum.

In a 2-year mouse feeding study at 2 and 6 ppm, the oncogenic potential was negative up to 6 ppm (HDT). The study was core-minimum.

In an 18-month mouse feeding study at dosages of 0.1, 0.2, 0.4, and 0.7 mg/kg/day, there was an increase in hepatomas in male survivors at 0.7 mg/kg/day. In a repeat 18-month mouse feeding study at 0.7 mg/kg/day (only level tested), the oncogenic potential was negative. Both 18-month mouse feeding studies were core-minimum.

Aldicarb was tested for mutagenicity and was negative in a mouse bone marrow cytogenetic assay, a rat hepatocyte culture DNA repair assay and an Ames assay. However, all three studies were classified as unacceptable.

10. Permethrin

The acute oral LD50 is 4892 mg/kg in male rats and 2712 mg/kg in female rats.

The teratogenic potential, in three different rat studies, was negative at 83 mg/kg/day (HDT), 200 mg/kg/day (HDT), and 225 mg/kg/day (HDT). Additionally, there was no maternal toxicity or fetotoxicity in these rat studies. Two of the studies were not core-graded, while the third study was core-minimum.

In mice, the teratogenic potential was negative at 400 mg/kg/day (HDT). The NOEL's for maternal toxicity and fetotoxicity were also 400 mg/kg/day (HDT).

Similarly, in rabbits, the teratogenic potential was negative at 400 mg/kg/day (HDT) and there was no maternal or fetotoxicity up to 400 mg/kg/day (HDT). Both the mouse and rabbit teratology studies were core-minimum.

The NOEL's in two different 3-generation rat reproduction studies were 100 ppm (HDT) and 180 mg/kg/day (HDT). One study was core-minimum, while the other was core-guideline.

In a third 3-generation rat reproduction study, a NOEL was not established at 500 ppm (LDT). At this level, offspring had liver and ocular histological lesions. At the 1000 and 2500 ppm dose levels, parents and offspring also had body tremors. The study was classified as core-guideline.

In a one-year dog oral study, the NOEL was 5 mg/kg/day. At the LEL of 100 mg/kg/day, there were increased alkaline phosphatase levels, increased liver weight and hepatocellular swelling. The study was core-guideline.

Seven long-term chronic feeding and/or oncogenicity studies, four in mice and three in rats, have been evaluated. There was evidence of hepatocellular and bronchioalveolar tumors in female mice. The rat studies were negative for oncogenicity. The NOEL for systemic toxicity in the seven studies was established at 5 mg/kg/day. Effects at the lowest effect levels included pharmacological liver effects. Two of the three chronic rat studies were core-minimum, while the third was core-guideline. One chronic mouse study was core-supplementary, while the three other mouse studies were not core-graded.

The mutagenic potential was negative in the Ames assay, mouse lymphoma, dominant lethal, rat cytogenetic, mitotic recombination in yeast, DNA repair in *E. coli* and *B. subtilis* and unscheduled DNA synthesis in human fibroblasts. The mutagenicity studies were not core-graded.

11. Conclusions

Based on the available data, carbofuran does not appear to pose a chronic health hazard because it has not shown positive oncogenic, teratogenic, or adverse reproductive effects. The data base is acceptable and is considered complete. Available data on the alternatives do not suggest adverse chronic effects to humans although the data bases are incomplete. The Agency has required that additional studies be conducted to complete the data bases.

Based on the LD50 values, the acute oral hazard of carbofuran is the same order of magnitude as fonophos, phorate, and terbufos, but is less than aldicarb, and greater than the other major alternatives.

B. Ground Water Contamination

In the FEDERAL REGISTER Notice (50 FR 41938) that initiated the Special Review for carbofuran, the Agency identified a concern for the potential for ground water contamination from carbofuran. Since the FEDERAL REGISTER Notice was issued, the Agency has conducted a preliminary ground water assessment (U.S. Environmental Protection Agency 1987d) by reviewing data from the EPA registration files to characterize the environmental fate of carbofuran. These data include laboratory and field studies submitted by FMC in support of carbofuran registration, Pesticide Root Zone Model (PRZM) modeling studies conducted by the Agency, and monitoring information from several States. A summary of these data as well as information concerning monitoring and modeling assessments follows.

1. Environmental Fate Data

Table IV-1 provides a summary of the environmental fate data on carbofuran. These data indicate that carbofuran is highly mobile and has a potential to leach. Table IV-1 also presents the environmental parameters listed by Cohen et al. (1984) as criteria for identifying leaching pesticides. In general, carbofuran falls well within the boundaries of leaching pesticides included in the review by Cohen et al. Carbofuran hydrolyzes slowly at low temperatures and low pH and may be persistent in ground water under these conditions. However, carbofuran is rapidly hydrolyzed in alkaline solution.

The data used to assess mobility and fate in the unsaturated zone of soil included photodegradation, aerobic and anaerobic degradation, and various leaching studies such as column leaching, partition coefficient determination, and Helling's Rf determination. (Note the unsaturated zone is a zone beneath the earth's surface which contains both water and air as well as solid materials.)

Photodegradation studies indicate rapid loss with half-lives of 19 to 32 hours on silica gel thin-layered chromatography (TLC) plates, but a slower loss on a silt loam soil. After 6 days of irradiation at 2500 microwatts/cm² and 26°C, 24 to 35 percent of extractable [¹⁴C] carbofuran was lost on this soil. However, 14 percent was lost when the soil was held in the dark over the same time. Photodegradation is not expected to be a major avenue of decay for the granular formulation. Application as a granular results in a reduction of the surface area of the chemical available for photodegradation, and granules are often incorporated or mixed into the soil, further reducing the surface area.

TABLE IV-1.

Related Environmental Fate Characteristics
for Carbofuran Compared with Those of Some
Pesticides That Have Been Found to Leach*

<u>Name of Characteristic</u>	<u>Carbofuran Characteristics</u>	<u>Charact. of some pesticides known to leach*</u>
K_d (soil absorption coefficient)	a) 0.01 to 2.22 for sand (1% OC) to silty clay lm (7.5% OC) b) 0.25 (sand, 0.4% OC) to 2.2 (si cl lm, 7.5% OC) c) 0.10 (sand, 0.85% OC) to 1.23 (sandy lm, 3.7% OC)	< 5, usually less than 1 or 2
K_{oc} (soil organic carbon absorption coefficient)	a) 1 to 30 b) 30 to 63 c) 12 to 33	< 300 to 500
Water solubility ug/ml	700 (20 C)	> 30
Henry's law constant (atmos-L/mol)	8.3×10^{-6}	< 10
Photolysis, half-life, days	5 (aqueous) unacceptable soil data	> 7
Soil persistence, half-life, days	a) 50 to 120 (field) b) 3 to ca. 350 (lab) c) 10 to 120 (12 Canadian field sites, soil texture varied from sand to clay) d) 60 (anaerobic lab) e) 120 (anaerobic lab)	> 14 or 21
Hydrolysis rate half-life, days	pH 9: 0.65 pH 6.2 & 7: 300	> 175

*Characteristics of some leaching pesticides are based on observations by Cohen et al. (1984) on pesticides reported to occur in ground water after agricultural use. These values must not be interpreted as providing a strict boundary between leaching and non-leaching pesticides.

In aerobic and anaerobic soil degradation studies carbofuran has exhibited a wide range of half-lives, making it difficult to generalize about field conditions. In one study conducted on six nonsterile midwestern soils (25°C, 70 percent field capacity, pH 5.4 to 7.9, 5 ppm concentrations -- with field capacity roughly equivalent to the soil water held at 0.3 bar tension), half-lives were around 7 days. In contrast, another study of four soils (25°C), 95 to 100 percent field capacity, pH 5.9 to 7.8, 5 and 10 ppm concentrations), resulted in half-lives of 2 to 4, 8, 54, and greater than 54 weeks. The primary mode of aerobic degradation would appear to be microbial, as a study on a clay loam soil showed half-lives of 8 and 54 weeks in nonsterile and sterile soil, respectively. Under anaerobic conditions, degradation of labeled carbofuran was slow in incubated samples of sandy loam, clay loam, and loam soils. Total recovered radioactivity after 90 to 120 days was 60 to 82 percent of applied.

Field studies in Nebraska and Ohio also showed conflicting results. At application rates of 5.41 to 6.72 kg ai per hectare (ha) in Nebraska, the half-life was approximately 17 days. In Ohio, applications were both in the granular and liquid formulations. The liquid formulations showed a half-life of 46 days. Following in-furrow application of 3.11 and 4.16 kg/ai/ha of the granular formulation, half-lives were 94 and 117 days, respectively.

Carbofuran is only weakly adsorbed by soil organic matter and clay particles and has a Henry's law constant of less than 10^{-10} (Table IV-1), and is therefore expected to be quite mobile. Mobility studies showed classic tendencies for leaching pesticides including high mobility in sand and sandy loam soils with less mobility (but still high) on silts and clays, and low mobility on organic soils and a high correlation with organic matter. Helling's R_f (retardation factor) on several soils was as follows (1.00 = highest possible mobility, 0.00 = no mobility): 0.90 to 0.95 on sand and sandy loam soils (< 1.2 percent organic carbon); 0.75 to 0.77 in silt loam and silty clay loam soils (< 3.5 percent organic carbon); 0.49 to 0.56 in silt loam, sandy loam, silty clay, and silty clay loam soils (< 7.5 percent organic carbon); and 0.30 for a muck soil (16.8 percent organic carbon).

Some evidence exists that induction of more rapid microbial degradation of carbofuran occurs in soils which have been previously treated with carbofuran (Harris et al. 1984). If accelerated degradation with repeated use is generally as intense as found by Harris et al., then it could be the critical factor in determining whether carbofuran would leach to ground water in measurable quantities in settings of moderate hydrogeologic vulnerability.

2. Environmental Fate - Aquatic Application

Carbofuran is used on two aquatic crops; rice (AR, LA, MS, TX, and CA only) and cranberries (WA and OR only). In an anaerobic aquatic soil metabolism study the specific degradation rates of the parent compound were apparently not determined, however the majority of the parent compound apparently still remained 120 days after initiation of a permanent flood on the soil.

Nearly all of the rice produced in the United States is subjected to a continuous flood through most of the growing season and is grown on heavy soils. Mikkelsen and Evatt (U.S. Department of Agriculture 1973) state that: "Rice, a semiaquatic plant, benefits from flooded conditions during part or all of the growing season. Flooding is essential for optimum grain yields.... Usually clay, clay loams, silty clay loams, or silt loams are considered most desirable because they prevent excessive seepage losses. Other soils, including organic soils, can be used if they have a claypan or hardpan that can maintain up to 6 inches of floodwater." EPA has no evidence that carbofuran leaches to ground water through these types of soils.

3. Modeling Studies

A series of Pesticide Root-Zone Model (PRZM) simulations assisted in the understanding of the fate of carbofuran in the unsaturated zone. Since PRZM does not simulate transport in the saturated zone, the results of these simulations are at best indications of the potential to leach. This "potential" is often defined by mass or concentrations of residues, which reach a certain depth in the soil. For EPA assessments, this depth is typically 2 m. A discussion of each simulation follows.

Vero Beach, Florida: The PRZM was calibrated to the pesticide carbosulfan applied to grapefruit. Carbosulfan currently does not have a registration. The first degradate of carbosulfan is carbofuran, and the transformation is usually within hours or days. This model was used to determine parameters for carbofuran, which were used in simulation runs that accurately reproduced the field data. Carbofuran leached to a depth of 4 feet in sandy soil on August 18 from an application on July 22. Soluble concentrations ranged from 1 to 24 ppb. PRZM was able to duplicate these field results by assigning an adsorption partition coefficient (K_d) to carbofuran of 0.1 and a rate of decay of 0.027, which corresponds to a half-life of 25 days.

Corn Application Assessment in Iowa: Carbofuran was applied to corn in Iowa on a "loam" soil at a rate of 1.12 kg/ha. A partition coefficient of 0.1 and half-life of 25 days was used. When using these parameters calibrated for carbofuran in the Vero Beach simulations, residues degraded before they had a chance to leach below the root zone. When a much slower rate of decay (half-life of 1 year) was used, carbofuran leached to a depth of 2 m after about 2 years at concentrations around 100 ppb. It is expected that the rate of decay in Iowa would be slower than in Florida, due to the temperature dependence of microbial decay. Since it is cooler in Iowa, the rate of decay would be slower. However, the half-life probably would not be 1 year, but closer to a range of 50 to 100 days. This being the case, leaching would be minimal in most corn-growing regions with medium-textured soils.

Flue-Cured Tobacco Assessments in North Carolina: Although the nematicidal use of carbofuran is much less than the insecticidal use, rates of application are substantially higher for the nematicidal use, which includes flue-cured tobacco in North Carolina. In PRZM simulations at a rate of 6.7 kg ai/ha on sandy soil, which is not atypical for tobacco in North Carolina, leaching occurred on all simulations. When using similar parameters as calibrated for carbofuran in Vero Beach, carbofuran reached 2 m within 3 to 4 months at soluble concentrations ranging from 3 to 24 ppb. When using the much slower rate of decay (half-life of 1 year), soluble concentrations reached 1330 to 1640 ppb.

Tolerance Petitions for New Uses on Hops and Eggplant: Prior to a request for new registrations, tolerances were requested for use on hops and eggplant. Concurrently, EPA evaluated the leaching potential of carbofuran if used on these crops using the PRZM. Since hops are typically grown on non-leaching soils (such as clay or loamy soils) where they are grown in Idaho and Washington, PRZM simulations showed that carbofuran would not leach below the root zone. However, there is a small amount of leaching soil (such as sandy soils) in the Washington counties. If hops were grown on these soils and carbofuran applied, then simulations showed that 17 percent of applications would leach below 2 m, and soluble concentrations would exceed 30 ppb for 7 months of the year. On the other hand, simulations of eggplants grown in Florida and New Jersey showed potential for leaching. The three main reasons for this were (1) high recharge in Florida and New Jersey, (2) extensiveness of sandy soils where eggplants are grown (particularly in Florida), and (3) the higher rate for nematicide protection. With a double crop in Florida, soluble concentrations at 1 m (approximating the top of the water table) ranged from approximately 10 to 200 ppb all the

time, with concentrations in the range of 150 to 200 ppb for a 3-month period following application. For the single crop system in New Jersey and with the practice of irrigation, soluble concentrations at 1.8 m were greater than 50 ppb for 6-month periods during wet seasons, and 10 to 20 ppb during dry months when little rainfall followed application.

4. Monitoring Data

The monitoring data that EPA has reviewed are summarized below by state. These data should be considered in light of the lifetime health advisory of 36 ppb proposed by EPA's Office of Drinking Water. At present our data base contains monitoring data from CA, FL, IA, IL, LA, MA, MO, NE, NY, OK, OR, PA, RI, SD, and WI. Of over 2000 wells sampled (excluding studies where the number of wells sampled was not reported), 2.4% contained detectable residues.

New York: The Suffolk County Department of Health Services has been sampling "impacted" wells on Long Island for carbofuran since 1980 (New York Bureau of Water Resources 1986). Impacted wells are those used for drinking that are near fields where pesticides are used. As of 1985, over 16,270 analyses have been performed for carbofuran. The number of wells is not given, but are thought to be less than 7500. Residues of carbofuran were found in 30.3 percent of the samples, with an average concentration of 7.7 ppb and a median of 4 ppb. Since aldicarb was banned for use as a nematicide on potatoes in Long Island in 1979, the nematicides of choice have been oxamyl and carbofuran. However, sampling for aldicarb has also occurred during the same time period (1980 to 1985). The mean residue for aldicarb was 20.2 ppb with a median of 8 ppb, and an occurrence of residues in 30.4 percent of the sample population of 24,832. These data indicate that the environmental fate characteristics of aldicarb led to more persistence and higher residue levels in the ground water compared with carbofuran. The acidic conditions and low temperatures of Long Island ground water, coupled with sandy topsoil and shallow ground water depths, make Long Island a "worst case" situation for leaching pesticides. The Long Island findings for carbofuran are summarized below:

YEAR	SAMPLES	SAMPLES		AVERAGE	MEDIAN
		> = 15 PPB	1 - 14 PPB	CONCENTRATION (PPB)	CONCENTRATION (PPB)
1980	237	25 (10.5%)	102 (43.0%)	12.1	6
1981	606	51 (3.4%)	256 (42.2%)	7.4	5
1982	2807	99 (3.5%)	538 (19.2%)	8.4	4
1983	4651	215 (4.7%)	1262 (27.1%)	8.3	4
1984	3955	125 (3.2%)	1097 (27.7%)	7.0	4
1985	4021	257 (6.4%)	905 (22.5%)	7.1	5
Totals 16,277		772 (4.7%)	4160 (25.6%)	7.7	4

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Maryland: FMC Agricultural Chemical Group submitted at least three reports to EPA (1982, 1983a, 1983b) on field dissipation/groundwater monitoring studies they conducted on corn and potato test plots with sandy to loamy soils of low organic matter and with the depth to the water table generally being less than 20 feet. There were two plots that were treated in April 1981. The first is a corn plot treated with a single application of 10G, and the second is a potato plot treated with eight foliar applications of flowable carbofuran. A bromide tracer was also applied. Twenty wells were placed in the perimeter of the field, 10 to 20 feet from the edge of the field. The majority were placed in the direction of ground water flow. The top of the water table was between 15 and 20 feet from the soil surface. Shallow lysimeters at 4 feet and deeper lysimeters at 8 feet collected unsaturated flow samples. Neither tracer nor carbofuran was detected in the perimeter wells through November 1981. There were 588 samples with carbofuran detected in 14, all at less than 2 ppb. However, lysimeter samples showed the unsaturated movement of carbofuran during this time. A high of 292 ppb carbofuran was found in the shallow lysimeter in the corn field 9 weeks following application, and a high of 22 ppb was found in the shallow lysimeter 5 days following 4F applications in the potato plot. Carbofuran was detected in the perimeter wells after November 1981. Between November 1981 and November 1982, 714 samples were taken from the perimeter wells, 357 from each test plot. In the corn plot, 44 percent of these were positive, with 10 percent between 0.5 and 1.0 ppb, 25 percent between 1 and 20 ppb, 8 percent between 20 and 50 ppb, and a single high reading of 71 ppb. In the potato plot, 16 percent were positive, with 8 percent between 0.5 and 1.0 ppb, and 8 percent between 1 and 20 ppb, although the high for the potato plot was only 9 ppb. Carbofuran and the bromide reached the perimeter wells at nearly the same time, indicating the low retardation of residues.

The registrant also conducted a retrospective field study of a field with previous known usage of carbofuran and found no residues. The Agency's review of these data indicated the study was inconclusive.

Massachusetts: During the summer and fall of 1985, an Interagency Task Force conducted a ground water monitoring survey (Interagency Task Force 1985) for aldicarb, alachlor, carbofuran, 1,2-D, 1,3-D, dinoseb, EDB, and oxamyl. The wells sampled were drinking water wells near potato and tobacco fields and were only "impacted" wells. Of 146 wells tested, samples from 23 contained carbofuran residue levels with a range of 1.0 to 36.6 ppb. One reading, however, was above the 10 ppb Massachusetts guideline level for carbofuran. In contrast, aldicarb appeared in 59 of 146 samples, with 20 samples above the 10 ppb guideline level. The Task Force made the observation that aldicarb showed higher levels than carbofuran or oxamyl, which is similar to findings from other States.

Wisconsin: The Department of Agriculture, Trade, and Consumer Protection (1986) did a brief study designed to test the effectiveness of the Wisconsin aldicarb law. In this study they placed three wells just off-site and downgradient of three worst-case potato fields in Portage County. Since the Wisconsin aldicarb law prohibits aldicarb use on the same application site more than once in any two successive years, they also tested for carbofuran, which was probably used in off-aldicarb years. Of the nine samples taken, none showed any residues of carbofuran.

The Wisconsin Department of Natural Resources (Ward 1986) also did a comprehensive monitoring study of public drinking water supplies in several counties. Sampling 155 wells and taking over 160 samples (with replicates on a few wells), they found carbofuran only in one well. On three sampling dates of this well, positive levels were 15.0, 4.3, and 1.6 ppb.

Rhode Island: The U.S. Geological Survey (1984) monitored a specific field site growing potatoes with a known nematocide use history. The specific pesticides, rates, and dates were unknown. The top soil was sandy, with the water table located 6 to 30 feet below the surface. Positive findings of 2 to 7 ppb were found in April 1984 and low residues of 1 to 3 ppb were also found in December 1985.

The Department of Health (Rhode Island Department of Health 1985) did a more comprehensive sampling program of 8 towns, 1015 private wells, and 1535 samples. Of these, only 19 results were positive with a high reading of 19 ppb.

Iowa: A study by Kelley et al. (1986) of the Big Spring Basin in Iowa included sampling of public water supplies, nondrinking water wells, tile drains, and surface waters. In the area, carbofuran is listed as one of the seven most used insecticides. Sampling has been occurring since 1983. Between 1983 and 1985, none of the 120 wells sampled contained carbofuran. In 1986, only 4 of 184 wells sampled contained carbofuran, with a range of 0.01 to 0.06 ppb.

In a recent survey in IA of public water supply systems (41 of 954 used a surface water source, the remainder using ground water), carbofuran was detected in only one water sample at the 0.2 ppb detection limit (Iowa Department of Natural Resources 1988). By contrast, the corn herbicides alachlor, atrazine, and cyanazine were detected in 19, 100 and 48 of the water samples, respectively, all at the same detection limit. Presumably a significant percentage of water systems were located in areas where a significant amount of carbofuran use on corn had occurred in the vicinity.

California: As of 1986, the California Department of Food and Agriculture (1984) had sampled 680 wells (684 samples) in 33 counties and found only 1 positive finding in Riverside County at 0.5 ppb. The source of the positive remains unknown because no record of carbofuran use could be found within a 5-mile radius of the well.

In another study conducted jointly by the U.S. Geological Survey and EPA (Setmire 1986) seven samples in the San Luis Drain area were sampled for carbofuran. Three were positive, between 0.05 and 0.38 ppb. Only seven samples were analyzed for carbofuran in this study because only seven wells had documented carbofuran use.

Nebraska: In a regional assessment study (Chen and Druliner 1985), 76 samples were analyzed for carbofuran in corn-growing regions that had a general insecticidal use pattern for carbofuran. There were only two unquantifiable detections for carbofuran at less than the minimum quantitative limit of 16 ppb.

Kansas: In the same joint regional assessment study as described for Nebraska (Perry 1986) carbofuran was not detected in any of the 27 samples at a 16 ppb minimum reporting limit.

Florida: The Florida Department of Agriculture (Fong 1986) is conducting a statewide survey of drinking and irrigation wells identified as "sensitive" based on hydrogeology and pesticide use. Initial results from Dade County (six wells), Jackson County (eight wells), and Palm Beach County (eight wells) all were negative for carbofuran with a detection limit of 0.4 ppb. Although specific usage of carbofuran around these wells could not be verified, wells generally were chosen based on proximity to high pesticide use.

Other surveys of private or public drinking water wells in IA, NE, IL have also detected carbofuran in ground water at a very low frequency. In a survey in IA of 33 water supply systems using surface water sources, approximately 30% of the samples were found to contain carbofuran with a detection limit of 0.1 ppb. Of other commonly used pesticides (all herbicides), atrazine, cyanazine, alachlor, and metolachlor were detected more frequently whereas metribuzin, trifluralin, butylate, and 2,4-D were detected less frequently than carbofuran in these samples from public water supplies from surface water sources.

In summary, the Suffolk County, NY study and FMC monitoring study in MD indicate that carbofuran may be found in ground water after its use in areas of high hydrogeologic vulnerability (i.e., sandy soils and shallow ground water depths). However, some state-wide surveys suggest that the

occurrence of carbofuran in ground water may be rare in areas that do not have these characteristics. Carbofuran may be found in surface waters used as drinking water sources, based upon its high water solubility and low vapor pressure and the results of the IA study above. Undoubtedly more surface water studies exist in the public domain. A comprehensive review of the surface-water data is recommended to complement this ground-water review.

5. Conclusions

Carbofuran is a mobile pesticide, which if sufficiently persistent, has a high likelihood to leach to ground water. However, the persistence of carbofuran in surface soils is highly variable, and until additional data are obtained to enable a reliable prediction of carbofuran persistence in different soils, we cannot determine how much of a ground-water contamination problem exists in areas of moderate hydrogeologic vulnerability. In sandy soils, it is clear that carbofuran can impact ground water at the tens of part per billion level as a result of agricultural use.

Under certain conditions carbofuran residues could persist once leaching to ground water has occurred. The conditions that lead to persistence in ground water are low pH and low temperature, conditions that result in slow rates of chemical hydrolysis. Since these conditions are not widespread in the United States, most leaching of carbofuran will probably not result in concentrations at the wellhead. Ground water conditions of low pH and temperature exist generally in the Northeast. The monitoring information for Long Island, New York; Massachusetts; and Maryland show the highest and most frequently found residues in ground water. In the comprehensive survey of "impacted" wells in Suffolk County, 30.3 percent of 16,277 samples collected between 1980 and 1985 were positive for carbofuran. However, only 4.7 percent of the samples contained over 15 ppb carbofuran. In Maryland, residues of carbofuran were consistently found in wells placed in the shallow, medium, and deep portions of the underlying and offsite aquifer, with a high reading of 71 ppb found near corn and potato field sites (sandy soil, shallow ground water, and high recharge). In the Massachusetts study, 23 of 146 "impacted" wells tested showed carbofuran residues with a high of 36 ppb. On the other hand, monitoring from the other States indicate much lower frequency and magnitude of positive residue findings.

In general, the available monitoring data indicate ground water concentrations above 36 ppb, the draft lifetime Health Advisory Level, will only occur in localized, extreme situations. It is expected that most of the nematocidal uses are the ones that pose a threat to ground water. The insecticidal uses of carbofuran will, in most cases, not pose a threat to ground water. Exceptions could occur in hydrogeologically sensitive environments such as Florida. The Agency will require registrants to amend their labels' current ground water advisory statement in an effort to further reduce the potential of ground water contamination from carbofuran use.

V. REGULATORY OPTIONS AND RISK/BENEFIT ANALYSIS

A. Introduction

FIFRA requires EPA to weigh the risks against the benefits for the pesticide uses of concern to determine whether continued registration would generally cause unreasonable adverse effects on the environment. Chapter II describes the risks posed by exposure of birds to carbofuran. Chapter III identifies the major alternative pesticides to carbofuran and describes the benefits of continued carbofuran use. Chapter IV describes the Agency's assessment of the human risks from carbofuran and its alternatives. The end of these chapters summarize EPA's conclusions concerning carbofuran and its alternatives. This chapter identifies the regulatory options available to EPA to reduce the risks from carbofuran use. EPA evaluated the risks and benefits of each option.

B. Development of Regulatory Options

There are three principal options for regulating the use of carbofuran as follows:

- Option 1 - Continuation of registration without changes,
- Option 2 - Continuation of registration with modifications to the terms and conditions of registration, and
- Option 3 - Cancellation of registration.

Adoption of Option 1 would be appropriate when EPA has concluded that the level of risk is acceptable compared to the benefits of use and that further risk reduction measures are not necessary to assure that the use of the pesticide meets the statutory standard for continued registration. Adoption of Option 3 would be appropriate when EPA has concluded that the risks from a use outweigh the benefits of that use. In this case these risks cannot be mitigated to an acceptable level when compared to the benefits by any other measures short of cancellation.

Option 2 is appropriate when the risks of a pesticide use can be reduced to a level where the benefits of use outweigh the risks. This risk reduction is accomplished by modifying the terms and conditions of the pesticide's registration. These modifications, which are usually expressed through the pesticide's labeling, are generally changes in the way the pesticide is used. These changes are designed to reduce exposure to the pesticide, thereby reducing or eliminating the risk from the pesticide. In the discussion that follows, risk reduction measures that the Agency considered are evaluated for their potential effectiveness and feasibility.

1. Adding label precautionary statements

EPA considered requiring additional precautionary labeling regarding the risk to birds from the use of carbofuran.

EPA determined that additional labeling would not significantly mitigate the risk to birds. Carbofuran is already a restricted use pesticide on the basis of the toxicity to birds and limited in use only to certified applicators or persons under their direct supervision. Also, extensive environmental hazard warning statements already appear on the label, including endangered species conservation measures, warnings regarding secondary poisoning of birds of prey, and others. Despite the restricted use classification and the warning statements, bird kill incidents have occurred.

2. Limiting application to certain months

EPA considered limiting carbofuran application to certain months because most of the bird kill incidents occurred during the major use season from April to June. EPA determined that such a limitation would be inappropriate. Carbofuran must be applied during certain times of the year to be effective. These are the seasons when it is now normally applied. Eliminating its use at this time would essentially result in cancellation.

3. Limiting application to certain geographic areas

Because most of the bird kill incidents involved waterfowl, EPA considered limiting carbofuran application to areas outside the areas that constitute the major waterfowl migration flyways. North American flyways are broadly described according to general north and south routes, with the principal routes including the Pacific, Central, Mississippi, and Atlantic Flyways. However, the boundaries of these north and south corridors are not precisely delineated, and there is also considerable movement of birds east and west across these corridors. Biotic factors such as local availability of food and abiotic conditions including localized weather conditions and topographic features can significantly influence a bird's migratory path. These factors can result in annual, seasonal, or even daily shifts in the migratory route of a bird.

By not allowing carbofuran application in these areas, the risk to migrating waterfowl could potentially be reduced. However, eliminating the use of carbofuran in the flyways would also affect a large portion of the usage of carbofuran.

Another consideration is that numerous groups of birds other than waterfowl are exposed to carbofuran. Limiting the application of carbofuran in certain geographic areas to protect

waterfowl would not protect waterfowl or other taxa of birds in the remaining geographic areas.

4. FMC Corporation's risk reduction program

FMC Corporation proposed a risk reduction program that included several measures the company claims will reduce the risk to birds (FMC Corporation 1986c and d).

a. Major points of FMC's program

The major points of FMC's program are as follows:

Reduce percent active ingredient (ai): Voluntarily remove carbofuran 15G from the market but retain the Federal registration. Carbofuran 10G would remain as the formulation with the highest percent ai until FMC has demonstrated to EPA "that avian risks from 15G are at, or have been reduced to, acceptable levels" (FMC Corporation 1986c).

Reduce application rate in corn: Reduce maximum application rate for corn from 4 to 1 lb ai/A based on a 40-inch row space.

Substitute "T" band for band application: "T" band is an application method combining band and in-furrow application. When using in-furrow application, granules are dropped into the furrow and covered with soil. When using band application, granules are applied as a 7-inch band on the soil surface and are then incorporated into the soil. "T" band application is a modified form of band application, which may leave as little as a 4-inch band, depending on the application equipment. The purpose of substituting "T" band for band application is to reduce the number of granules applied to the soil surface.

Other types of application such as in-furrow would be retained.

Conduct research: Begin studies to determine if changes in the formulation could further reduce risk. Such changes could include changing the size, shape, and color of the granule, modifying the release rate, and using repellents or alternate carriers.

Aid equipment research: Aid research on new farm equipment and subsidize growers for the purchase of new equipment if it is developed.

Implement educational program: Implement an educational program to educate growers on the proper use of carbofuran to reduce the risk to birds.

Provide funding for endangered species: Provide \$1,500,000 over the next 5 years to provide for endangered species relocation and/or to purchase or preserve critical habitat.

b. Evaluation of FMC's program

EPA evaluated each point of FMC's program, as discussed below.

Reduce the percent ai: Such a reduction would eliminate the risk associated with the 15G. However, the risk associated with the other formulations, including 10G, would remain. Six field studies used 10G and resulted in birds being killed. Nine bird kill incidents were reported for 10G. In addition, EPA estimates indicate that a great number of granules would be exposed on the surface, regardless of formulation and these other formulations are toxic to birds. In addition, if the 15G were not available, more granules would need to be applied to attain the same rate of application of the active ingredient. For example, application of 10G results in approximately 50 percent more granules applied than from 15G. A single granule of 10G is lethal to small birds.

Reduce application rate in corn: Assuming the typical 35-inch row space, rate reduction from 4 to 1 lb ai/A would result in a maximum of 72 percent fewer granules applied. Although this would reduce the number of granules applied, field studies indicate that application of 1 lb ai/A would result in approximately the same level of avian mortality as at 4 lb ai/A application rate.

Substitute "T" band application: Based on studies with band and in-furrow application, estimates indicate that a 4-inch "T" band would result in 43 percent fewer granules remaining unincorporated than would occur with a 7-inch band application.

Even though "T" banding may reduce the number of granules exposed on the soil surface, a similar reduction in the number of birds killed per acre does not appear to occur. Birds were killed in field studies using band application at 4 and 1 lb ai/A and in-furrow application at 1 lb ai/A. "T" banding is a method of application that results in an intermediate number of granules exposed on the soil surface relative to the two types of application tested in these field studies. Therefore, "T" banding is expected to yield results within the same range.

Conduct research: Research regarding reformulation of granular carbofuran products may have the potential to result in a formulation less attractive to birds. However, until such research is conducted and the findings submitted, EPA does not have the information with which to base such a regulatory decision.

Aid research of new farm equipment: The development of equipment that leaves fewer unincorporated granules would result in less surface exposure from carbofuran. Subsidizing growers would provide incentive for growers to buy the new equipment. However, application equipment that incorporated greater than 99 percent of the carbofuran granules has been developed for pine seed orchards and was tested in four States, resulting in 0.4 to 1.4 birds killed per acre. Two potential secondary poisonings occurred. In addition, EPA's assessment of the risk associated with 99 percent incorporation indicate that the risk to birds under such exposure scenarios is still significant.

Implement educational program: Educating users in the proper application of carbofuran would result in greater assurance of compliance with risk reduction measures and would probably help to ensure that carbofuran is applied properly. However, field studies and bird kill incident data indicate that proper application of carbofuran results in birds being killed.

Also, an educational program concerning the proper application of carbofuran in rice was mutually conducted by California and FMC Corporation between 1985 and 1986. The total number of birds reported dead decreased from 201 in 1985 to 162 in 1986. The number of incidents was reduced from 10 in 1985 to 7 in 1986. The number of incidents may be a better indicator of risk than the absolute number of carcasses found because of the problems associated with carcass search efficiency and removal of carcasses by predators and scavengers.

Provide endangered species funding and relocation: In limited situations such as with dicofol, the U.S. Fish and Wildlife Service has accepted funding and relocation as a way to offset the impact to endangered species.

However, the Aplomado falcon has already been relocated from Mexico into Texas in an attempt to reintroduce it into its historic range. This area of Texas is an area of carbofuran use.

5. EPA's risk reduction program

EPA developed a modified risk reduction program to determine if a more stringent risk reduction program would result in risk reduction.

a. Major points of EPA's program

The major points in EPA's program are as follows:

Cancellation of 15G: As opposed to temporarily removing 15G from the market, 15G would be cancelled. 10G would remain as the formulation with the highest percent ai.

Reduce application rate in all crops: In addition to requiring FMC's rate reduction for corn, rate reduction would be required on other crops as well.

Requiring in-furrow application only: In-furrow application would remain as the only registered application method for carbofuran.

b. Evaluation of EPA's program

As discussed under FMC's program, eliminating 15G would remove the risk associated with the use of 15G. 10G would remain and be applied using in-furrow application, which results in the greatest degree of soil incorporation of all the methods for applying carbofuran. However, the use of 10G would nonetheless pose a substantial risk to birds. More granules would be applied by using the 10G formulation than the 15G. Moreover, field studies indicate that enough granules are exposed to present a comparable risk to birds in spite of rate reduction and in-furrow application. Also, a 1 lb ai/A limit for other crops may not be efficacious.

6. Comparison of the two programs

EPA initially analyzed the two risk reduction programs by calculating exposure reduction in terms of the number of granules remaining unincorporated on the surface of the soil. These granules would be readily available to birds. The numbers under several application regimes are as follows:

<u>Current Application</u>	<u>Estimated Number of Granules Available to Birds Per Acre</u>
10G, 4 lb ai/A, 7-inch band	2,648,000
15G, 4 lb ai/A, 7-inch band	1,768,000

If either risk reduction program were implemented, the number of granules available on the surface of the soil would decrease. The following table compares the estimate of the number of granules that would be readily available to birds on the surface of treated fields.

<u>Current proposed use program</u>	<u>Granules per acre</u>	<u>Aggregate change</u>
<u>FMC Program</u>		
15G - Voluntary suspension	---	---
10G, 4 lb ai/A, 7-inch band	2,648,000	+ 880,000
10G, 1 lb ai/A, 7-inch band	662,000	- 1,106,000
10G, 1 lb ai/A, 4-inch band	337,000	- 1,431,000
<u>OPP Program</u>		
15G - Suspension/cancellation	---	---
10G, 4 lb ai/A, 7-inch band	2,648,000	+ 880,000
10G, 1 lb ai/A, 7-inch band	662,000	- 1,106,000
10G, 1 lb ai/A, in-furrow	95,000	- 1,673,000

These estimates indicate that the number of granules per unit area would be reduced. However, these estimates do not consider the number of granules available below the surface. Birds may consume these granules while foraging for seeds, grit, or invertebrates. Thus, these estimates of the number of granules on the surface are likely an underestimate of the total potential exposure.

Most importantly, the available field data do not indicate that the reduction in potential bird poisonings is proportional to the reduction of the number of granules. The field studies were performed at different application rates with different application methods, sites, and locales. However, avian mortality for direct carbofuran poisoning occurred in all studies and up to 60 days after application. Secondary poisoning of predatory and scavenging birds also occurred. The data indicate that the remaining number of granules would still result in avian mortality. As discussed earlier, one granule of either 10G or 15G is sufficient to kill a small bird. Therefore, risk reduction will occur only to the extent that the probability of birds consuming a single granule is decreased.

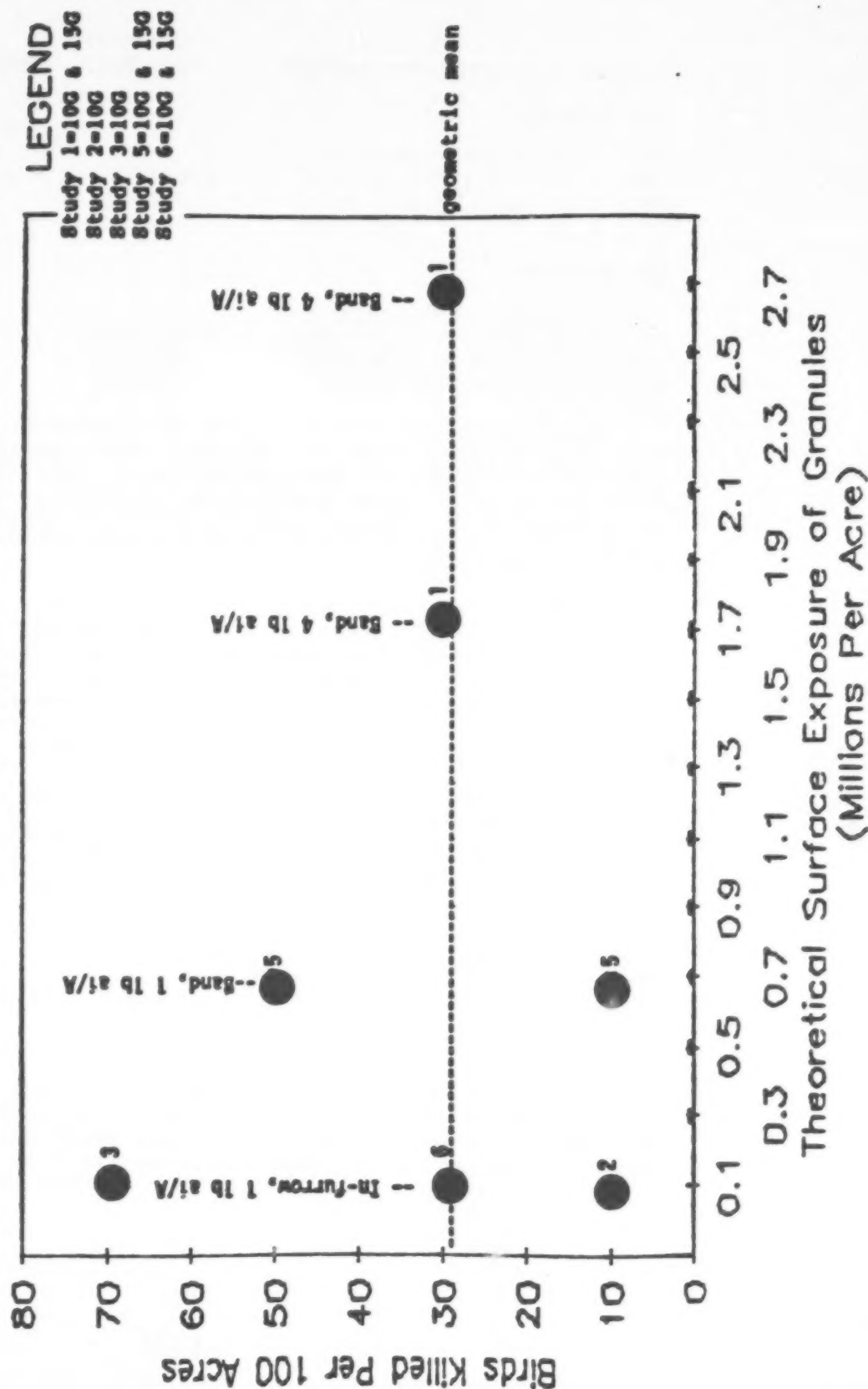
Field data are available for the following combinations of formulation and application methods:

<u>Formulation</u>	<u>Application</u>
10G and 15G	7-inch band at 4 and 1 lb ai/A
10G and 15G	In-furrow at 1 lb ai/A
10G	Specialized equipment at 25 lb ai/A

These data are plotted in Figure V-1. The estimated number of granules remaining unincorporated on the surface of fields is plotted against the number of reported avian mortalities per 100 acres of searched area. The resulting curve is not a regression, and a correlation coefficient was not calculated. The purpose of

Figure V-1

RATES OF AVIAN MORTALITY OBSERVED DURING CARBOFURAN FIELD STUDIES.



representing the studies in this way is to show a possible relationship between the exposure of granules on the soil surface and the rate of avian mortality. As these data are essentially not statistically comparable, they may not be used to establish a quantifiable relationship. The graph shows that the rate of bird poisonings is roughly constant within the data points available. In other words, application of 10G at 1 lb ai/A in-furrow results in about the same rate of poisonings as 10G at 4 lb ai/A using a 7-inch band, even though the former application resulted in 100,000 granules per acre and the latter 2.6 million granules per acre.

If in-furrow application at 1 lb ai/A is used, less granules would remain on top of the soil (excluding spills). These granules would be concentrated in the seed rows. However, these few granules are of concern because field studies showed avian mortality under these application conditions. A possible explanation is that birds do not encounter these granules by chance but may be attracted to them because they are similar in appearance to grit.

Data are not available to estimate the potential bird poisoning rate below the 10G 1 lb ai A/in-furrow application scenario. Thus, while it is probable that some combination of lower application rates and changed application techniques could result in reductions in the rate of bird poisonings, EPA lacks the data to determine an acceptable combination and whether or not that combination is efficacious.

The rate of avian field mortality that is observed appears to be influenced by the number of birds that fly into a treated field, particularly if flocks consist of small sensitive species such as horned larks. If a flocking species or other unusual concentration of birds occur in an area of carbofuran treatment, a large kill could occur and in fact did occur in Field Study 1. This would skew the flat mortality rate in Figure V-1. However, as FMC Corporation indicated in their public comments, this is an unusual event. EPA agrees that flocking will not necessarily occur each time carbofuran is applied, and thus did not use the horned larks mortality in comparing the field studies.

FMC (1986a) suggested that because many more birds were observed in Texas (Field Study 6) than in Iowa or Illinois (Field Study 5) and because proportionally fewer birds were killed in Texas, it could be concluded that the in-furrow technique used in Texas resulted in a reduction of avian mortality below that observed in Iowa and Illinois, where applications were made using the banded technique. However, it was not possible to make a simple comparison of the total number of birds observed on censuses. This comparison is deficient because it does not take into account the ecology and sensitivity of the species exposed, the search efficiency, number and frequency of searches

(different at different sites), removal of carcasses by predators and scavengers, and other effects such as weather, which even the authors of the Corn Belt study suggested could have reduced the toxicity of the granules at the Iowa site. Moreover, it is difficult to quantify the effect of the unconventional methods employed to find and cover granules in the banded Corn belt studies. All these factors could substantially affect the number of observed mortalities, which in turn could affect the comparisons made on the basis of proportional mortalities.

Therefore, EPA concluded that while net reductions in the number of granules available to birds would likely result from decreasing application rates and changing the methods of application, the field studies indicate that the remaining number of granules would still result in comparable rates of direct avian mortality, even with applications of 10G carbofuran reduced to as low as 1 lb ai/A using in-furrow application.

C. Risk/Benefit Analysis of Regulatory Options

EPA has concluded that if the registrations of granular formulations of carbofuran products were continued without restriction (Option 1), the risks to birds resulting from carbofuran application would exceed the benefits associated with carbofuran use.

EPA evaluated the ramifications of amending the terms and conditions of registration (Option 2) by modifying labeling to include additional precautionary language, limiting application to certain geographic areas or certain months of the year, or by imposing risk reduction measures through various risk reduction programs. EPA determined that none of these measures would adequately reduce the risk to birds to bring the risks and benefits of carbofuran into balance.

The high risk carbofuran poses to birds is apparent from the fact that as little as one granule can kill a small bird. Carbofuran generally is considerably more toxic than its alternatives (Table II-14 and Table II-15). The risk carbofuran poses to birds is also highlighted by the over 40 documented incidents of carbofuran poisoning. All available field studies have also indicated the risk carbofuran poses to birds.

As a result, EPA considered cancellation (Option 3), which would eliminate the risks to birds from carbofuran exposure from these sites. The following section summarizes the risks and benefits of carbofuran use on individual use sites.

The following crop-by-crop discussion notes whether there have been bird kills associated with field studies or incident reports linked to the application of carbofuran in a specific crop. Details pertaining to these kills are described in Chapter

II. It should be noted, however, that lack of a documented bird kill associated with a particular use site does not suggest that there are no kills associated with the use of carbofuran have occurred on the use site.

As discussed in Chapter II, exposure is often comparable among sites, and bird kills associated with one site strongly suggests that kills also will be associated with sites having similar exposure. When EPA lacks documentation of kills for a given site, this does not necessarily reflect a true absence of kills associated with the use of carbofuran at that site. Rather, the lack of documented kills may be due to factors including lack of systematic observations for that site and the lack of a effective system for reporting and verifying bird kills associated with pesticide use.

1. Corn

Corn is grown throughout an extensive geographic area in the United States. As a result, the greatest variety of species and number of birds are expected to be found in corn fields compared to the other 9 use sites that were analyzed. These birds include waterfowl, marsh and shorebirds, upland game birds, and songbirds. Endangered species found in corn fields may include the Aleutian Canada goose, Mississippi sandhill crane, whooping crane, Attwater's greater prairie-chicken, piping plover, and bald eagle.

Researchers have documented birds using corn fields throughout the crop cycle for a range of activities, including feeding, resting, nesting, and brood-rearing. Since carbofuran may be applied both at-planting or postemergence, any of these avian activities may occur at the time of application.

These birds will mainly be exposed to carbofuran granules on the soil surface. Agricultural engineering and field studies confirm that application of granular pesticides, including carbofuran applied at-planting, results in granules exposed on the soil surface. This is of concern because data from acute toxicity testing indicate the carbofuran is highly acutely toxic and that one granule can provide a sufficient dose to kill some small birds.

EPA estimated the number of LD50s/sq ft based on current label information, which resulted in a minimum of 68 and maximum of 2211 LD50s/sq ft for songbirds and a minimum of 6 and maximum of 187 LD50s/sq ft for upland gamebirds and waterfowl. These estimates indicate that the use of granular carbofuran in corn poses a potential risk to birds. Evaluation of the field studies indicate that avian mortality occurred at estimated risk levels as low as 6 LD50s/sq ft. All of the LD50s/sq ft estimated for the three representative bird groups exceed this value.

The risk identified by the LD50s/sq ft analysis is corroborated by the field studies and bird kill incident reports. There was bird mortality resulting from direct carbofuran poisoning in all of the field studies conducted in corn. In addition, mortality was also documented as reported bird kill incidents. Corn was the site for which the second highest number of bird kill incidents (6) were reported. Direct poisoning has resulted in killing waterfowl, songbirds, and other species from carbofuran application in several states.

Secondary mortality to predatory birds such as hawks and bald eagles has also occurred in the field studies and been reported as secondary kill incidents. Because of the problems inherent in studying raptor populations, it is very difficult to effectively monitor secondary poisoning. Also, the problems associated with the reporting of bird kill incidents are even greater with secondary poisoning. Birds secondarily poisoned are even less likely to be found than those killed from direct poisoning.

Because of its widespread use of carbofuran on corn, EPA is concerned about the potential impact on populations of declining birds, which may be exposed by either direct or secondary poisoning. Population declines of predatory species including the red-shouldered hawk, loggerhead shrike and small birds such as the field sparrow and American goldfinch have been documented.

EPA does not consider granular carbofuran to be the sole causative factor in the decline of the bird species discussed. However, carbofuran is one of the most highly toxic pesticides to which these birds are exposed. Given its widespread use in corn, carbofuran is likely to be responsible for bird deaths in these species. Therefore, EPA concluded that granular carbofuran can be an important additive factor in the decline of these birds.

Carbofuran is applied as a preventive treatment when seeds are planted to 4.5 to 5.5 million acres of corn or 5 to 7 percent of the U.S. corn crop per year. Carbofuran is used primarily to control the corn rootworm and corn borer complexes. Usage has been declining and is approximately one third of the 1978 level. By 1986, the market share held by carbofuran dropped to less than 15 percent, where in terms of acre treatments carbofuran ranked fourth out of the five major corn insecticides.

EPA evaluated data that indicated that several efficacious alternatives of comparable cost are available. Alternatives are available both for use at-planting, the most common time of application, and later in the season when pest problems actually occur. No difference in yield was demonstrated between carbofuran and its alternatives, and the economic impact of

cancellation is negligible. Also, carbofuran appears to pose a greater risk to birds than the alternatives.

Carbofuran has a broad spectrum of control and residual systemic properties, making it attractive to certain growers. Carbofuran is one of only two carbamates available for rotation between organophosphates and carbamates in corn to delay resistance in soil pests. EPA recognizes that some cross-resistance with organophosphates could occur because both affect acetylcholinesterase. It should be noted that repeated use of carbofuran may lead to an apparent increase in soil microbial populations capable of reducing its effectiveness.

Efficacious and less hazardous alternatives to carbofuran are available at comparable cost. This may be compared to the risk to birds, which has been demonstrated to be quite high based on both laboratory and field information on carbofuran. Therefore, EPA concluded that the risk to birds outweighs the minor benefits and proposes cancelling carbofuran use on corn.

2. Sorghum

Birds such as marsh and shorebirds, game birds and songbirds and waterfowl, are expected to be in sorghum fields at the time of carbofuran application. These birds may use sorghum fields for many activities including feeding and nesting. Endangered species that may be exposed include the Attwater's greater prairie-chicken, Aplomado falcon, and whooping crane, which may frequent sorghum fields in Texas. In one case, whooping cranes had to be chased from a sorghum field treated with granular carbofuran.

EPA estimated the LD50s/sq ft in sorghum for songbirds, upland gamebirds, and waterfowl. The minimum and maximum LD50s/sq ft for these birds range from 56 to 1033 for songbirds, and 5 to 89 for upland gamebirds and waterfowl.

Carbofuran is applied to approximately 640,000 to 2.04 million acres of sorghum, which is 4 to 12 percent of the acres planted. It is primarily applied at-planting to control later infestations of chinch bug and greenbug. Carbofuran is the first or second most commonly used insecticide on sorghum.

For greenbug control, pesticides may be applied at-planting as a preventive treatment or later in the season if problems with greenbugs arise. Several alternatives are available, but terbufos is most likely to be used. In terms of product performance, terbufos appears to be equally effective.

Most years with normal pest infestations are not expected to pose major problems, and cancellation of carbofuran would not have an adverse impact (at most \$0.4 to \$0.9 million annually) on

sorghum growers. However, in years of high chinch bug infestations, aggregate cost increases and the value of yield reductions could range from \$7.4 to \$9.3 million in eastern Kansas if aldicarb is used. Such infestations occur every 5 to 10 years. During these years, yield losses may be incurred with the use of aldicarb as an at-planting treatment. Foliar treatments are available, but were not considered when estimating the economic impact. These treatments may not always be effective because of problems with treatment timing, limited availability of scouts, and chinch bug reinfestations.

Sorghum has received considerable IPM attention. Due to the relatively low return on sorghum, a number of pest management and cultivation practices have already been incorporated into sorghum culture to reduce the need for pesticide application. None of these practices will completely replace the use of insecticides on sorghum, but they will help reduce the number of applications and the amount of insecticides used.

EPA concluded that the risk to birds outweighs the minor benefits and therefore proposes to cancel the use of carbofuran on sorghum.

3. Soybeans

Birds that are expected to be present at the time of carbofuran application to soybeans include marsh and shore birds, gamebirds, and songbirds. These birds may use soybean fields for a variety of activities, including feeding, brood-rearing, nesting. Endangered species expected to be present at application include the bald eagle, whooping crane, and Mississippi sandhill crane.

The minimum and maximum LD50s/sq ft were estimated. They ranged from 68 to 2104 for songbirds, and 6 to 178 LD50s/sq ft for upland gamebirds and waterfowl, which are values that demonstrate that carbofuran poses a potential risk to birds.

As indicated previously, this use pattern is similar to corn, and thus the risk expected from this use should also be similar. A bird kill incident from direct carbofuran poisoning was reported and is associated with corn and soybean fields and involved waterfowl, blue jays, grackles, and killdeer.

Carbofuran is applied to approximately 210,000 to 280,000 acres of soybeans, which is less than 1 percent of the U.S. soybean crop. Carbofuran is used mainly to control the Mexican bean beetle. With the exception of some of the southeastern states, the Mexican bean beetle is not a major pest on soybeans. Because carbofuran is applied at-planting, it is uncertain whether enough carbofuran will be present in the plant to control an infestation at pod set and fill, the critical stages of

Mexican bean beetle infestation. Thus, consultants and extension entomologists in the majority of the soybean-producing states recommend the use of foliar sprays later in the season to control the Mexican bean beetle. The use of resistant varieties of soybeans, early planting, and crop rotation are also recommended.

Alternatives are available at-planting and as foliar sprays later in the season. Efficacy data indicate that viable alternatives are available and are not expected to have adverse impacts on production costs. These costs may be as high as \$4.7 to \$5.5 million annually and occur primarily in the Southeast.

EPA proposes to cancel the use on soybeans because the risk to birds outweighs the minor benefits.

4. Rice

Rice fields offer attractive habitat to many types of birds, including migratory waterfowl. Diverse water species are expected to be present when carbofuran is applied, and hawk species are known to search rice fields for prey.

EPA estimated the number of LD50s/sq ft for rice. The result was a minimum of 156 and maximum of 261 for songbirds and 13 and 22 for upland gamebirds and waterfowl. All of these values indicate that carbofuran poses a potential risk to the representative bird groups.

The occurrence of over 20 bird kill incidents confirms the high risk to birds. (A field study in which birds were killed from carbofuran poisoning was also available on rice, but the Agency did not consider this study to be comparable to the other field studies because important information on the extent of the treatments and the performance of carcass searches was missing.) Over half of the bird kill incidents resulting from direct carbofuran poisoning occurred on rice. The numbers of birds involved ranged from 1 to 150, although the 150 ducks that were killed may have been from a misuse or resulted from carbofuran applied earlier in the year. In addition, secondary poisoning incidents involving marsh hawks and red-tailed hawks were also reported on rice.

Approximately 2 percent of all carbofuran or 5 percent of granular carbofuran marketed in the United States is used to control the rice water weevil on rice in Arkansas, California, Louisiana, Mississippi, Texas, and Missouri.

Carbofuran is the only pesticide registered to control the rice water weevil, a major pest of rice in all growing regions, and treatment varies among California and southern rice-growing states. All control recommendations are based on annual population monitoring.

Since no alternative chemical controls are available, pest control costs could decrease by approximately \$8.50 per acre or about 4 percent of the total variable operating costs in the Delta and 3 percent in California. Considering the savings from not applying carbofuran or any other pesticide, as well as the 7 percent yield loss, the estimated annual net revenue loss is approximately \$12.2 million or 10 percent of the net farm income of the impacted acres. Some marginal rice growers who normally rely on carbofuran may be forced out of business.

Government payments under the current U.S. Department of Agriculture farm program would decrease by \$6.1 million because of lower production. Subtracting the reduced government payments (\$6.1 million) from the rice industry impact (\$12.2 million) results in an estimate of the net loss to society of \$6.1 million.

EPA is unaware of any measures which would reduce the risk from carbofuran use on this site. Because of the substantial risks indicated by the estimate of the number of LD50s/sq ft and corroborated by the large number of reported bird kill incidents on rice, the risks outweigh the benefits on this site. Therefore, EPA proposes to cancel this use.

However, EPA recognizes that there are no chemical alternatives currently registered for use to control the rice weevil and only limited information pertaining to the availability and efficacy of non-chemical alternatives. Thus the substantial risks associated with carbofuran's use must be weighed against the substantial benefits. Because the Agency is concerned about the lack of chemical alternatives for control of the rice water weevil, as well as the risks associated with carbofuran's use, the Agency requests comments on the following issues:

- (1) the extent of usage of carbofuran to control the rice water weevil;
- (2) the economic impacts that would result from cancellation of carbofuran's use on rice;
- (3) the potential for other pesticides being registered to control the rice water weevil, particularly efficacy testing of such pesticides;
- (4) the potential for non-chemical control methods, including draining of fields and biological control organisms, to control the rice water weevil (particularly efficacy testing of such methods); and,
- (5) the availability of bird kill information on rice fields outside of California, and any information which would assist the Agency in interpreting the apparently extensive bird kills particular to that state.

5. Peanuts

Numerous species of birds may be present when carbofuran is applied to peanuts and may be engaged in a variety of activities including feeding, seeking cover, and resting. These birds include the Attwater's greater prairie-chicken, an endangered species, which may be exposed to carbofuran application in Texas. Since the use pattern is similar to corn, the expected risk is similar.

The LD50s/sq ft ranged from a minimum of 32 to maximum of 2632 for songbirds. The minimum and maximum LD50s/sq ft were 3 and 223 for upland gamebirds and waterfowl.

Approximately 136,500 acres of peanuts, which is 9 percent of the total crop are treated with carbofuran to control insects and nematodes. Efficacious alternatives are available for both uses. The generally higher rate of application for nematode control leads to higher treatment costs overall, regardless of the chemical used. The overall annual change in insect and nematode control costs if carbofuran were not available would not exceed \$4.0 million. The total variable costs of peanut production would increase 4 to 6 percent for alternative insecticides and 7 to 11 percent for alternative nematicides.

However, based on the estimated risks and minor benefits, EPA concluded that the risk outweighs the benefits and proposes to cancel the use of carbofuran on peanuts.

6. Tobacco

Numerous species of birds can be expected in and near tobacco fields. Tobacco fields tend to be small, thereby providing a high ratio of "edge" habitat to field area. Areas of fields adjacent to edge habitat would tend to have high levels of bird activity, which could include nesting, brood-rearing, foraging.

EPA estimated the minimum and maximum LD50s/sq ft for this use site. The results were 1368 to 3159 for songbirds and 114 to 267 for upland gamebirds and waterfowl. All of these LD50s/sq ft values are extremely high and represent the second highest number of LD50s/sq ft of the ten use sites analyzed.

Use of all carbofuran formulations has been declining in recent years in tobacco. Approximately 20,000 to 40,000 acres are treated each year, or 3 to 6 percent of the crop. A review of efficacy data indicate that effective alternatives are available, and yields of those acres normally treated would not be significantly reduced. The flowable carbofuran formulation is the preferred alternative. This formulation may also pose a risk to birds, but at this time field study data are not available to

evaluate the risk. These data are being required through the reregistration process.

A change from granular to flowable carbofuran would increase costs by approximately \$11 to \$20 per acre, which is less than 1 percent of annual variable production costs. A total annual production cost impact ranging from \$220,000 to \$800,000 is estimated for the current granular carbofuran user. Less than a 1 percent of the variable production cost increase for 3 to 6 percent of the U.S. tobacco crop may result, but should not affect tobacco prices. Output effects are not expected at the commodity or retail level.

Based on the estimated risks and the minor benefits, EPA concluded that the risks to birds outweighs the benefits of use and proposes cancellation of granular carbofuran on tobacco.

7. Cotton

Cotton represents less than 1 percent of both the granular and total carbofuran usage. Approximately 30,000 acres are treated, primarily in Texas. Although this represents minor cotton acreage, these fields may still be treated with carbofuran and birds may be exposed while nesting, brood-rearing, and foraging. Numerous avian species, including the endangered Mississippi sandhill crane and Aplomado falcon, may be exposed when carbofuran is applied.

The LD50/sq ft analysis in cotton resulted in a minimum of 68 and maximum of 527 for songbirds and minimum of 6 and maximum of 45 for upland gamebirds and waterfowl. All of these values indicate that carbofuran presents a potential risk to birds.

Carbofuran is used in cotton for preventive control of thrips. However, this use is controversial because some research indicates that this pest causes damage that reduces yield, while other research indicates that it does not.

Both at-planting and foliar treatments are available. Cancellation would result in aggregate farm level impacts totaling \$120,000, at most. Adverse economic impacts are not expected to occur for either the cotton industry or other interrelated sectors of the economy.

EPA concluded that the risk outweighs the minor benefits and proposes to cancel the use on this site.

8. Cranberries

Numerous species of birds may use cranberry fields. Birds have been observed in cranberry bogs and on the vegetated edges of the borders (Comment #2 listed in Appendix 12). Based on

known toxicity and estimates of exposure, potential risk to birds from carbofuran use on cranberries is high.

EPA estimated the number of LD50s/sq ft for cranberries. The resulting LD50s/sq ft were high. The minimum and maximum number were 1052 for songbirds and 89 for upland gamebirds and waterfowl. All of these values indicate that granular carbofuran poses a potential risk to birds.

Cranberries represent less than 1 percent of both the granular and total carbofuran usage. Approximately 400 lb ai are applied to 185 acres of nonflooded cranberries in Washington and Oregon. While no alternatives are registered for non-flooded cranberries to control the black vine weevil larval stage, acephate is an effective registered insecticide that controls the adult stage. Major annual impacts estimated at \$1.0 to \$1.1 million (\$7.0 to \$7.7 million over 7 years) are expected. These estimates do not include benefits provided by acephate, and therefore, may be overestimated.

EPA has determined that the risks outweigh the benefits of this use. Therefore, EPA proposes to cancel this use.

9. Pineseed Orchards

A variety of birds including predatory species are expected to be present at the time of application. Because carbofuran is applied to pineseed orchards in the southeastern United States in the winter and early spring, several species of overwintering passerine birds are expected to be exposed.

The LD50s/sq ft analysis for pineseed orchards resulted in the highest values of all of the crops analyzed. The minimum and maximum LD50s/sq ft ranged from 5170 to 10,002 for songbirds and 438 to 846 for upland gamebirds and waterfowl.

A field study in pineseed orchards evaluated the effectiveness of specialized application equipment. The Agency concluded that the equipment did result in a high degree of incorporation. However, some granules still remained unincorporated, and birds mortalities occurred. This field study also listed the different bird species observed foraging before carbofuran application to pineseed orchards in Mississippi, Florida, South Carolina, and Louisiana. Pine warblers were common to all sites, but many other birds, including loggerhead shrikes and several hawks were also observed. The possible secondary poisoning of two loggerhead shrikes was also noted.

Pineseed orchards also represent less than 1 percent of both granular and total carbofuran usage. Only 5 percent or less of the 10,000 acres of mature seed producing pine orchards are treated with 1500 to 7500 lb ai. Use on young seed orchards is

more important (20 to 50 percent of the acres), although usage is still estimated to be less than 100 lb ai. Aggregate annual economic impacts would be no higher than \$11,000 which represents a 2 to 3 percent increase in production costs.

Because the risks outweigh the minor benefits associated with use of carbofuran on this site, EPA proposes cancellation of the use of carbofuran on rice.

10. Sunflowers

Many types of birds, including waterfowl, game birds, songbirds use sunflower fields at times when they are likely to be exposed to carbofuran. These birds would be expected to frequent sunflower fields and border areas for feeding, nesting, cover, brood-rearing, and bedding.

The LD50s/sq ft analysis indicated a minimum of 68 and maximum of 1368 for songbirds, and 6 to 116 for upland gamebirds and waterfowl. All of these are high enough to demonstrate potential risk to each of the representative bird groups. Because of the similarity of this site to the other sites, such as corn, the risk is expected to be similar.

Sunflowers account for less than 1 percent of both granular and total carbofuran usage. From 1 to 5 percent of the acres treated in the U.S, which is 18,400 to 105,900 acres, are treated with a total 18,400 to 121,000 lb ai annually. Over the last few years, more cost-effective rescue treatments are replacing the use of at-planting insecticides such as granular carbofuran. No adverse impacts are expected for either sunflower producers or consumers.

EPA concluded that the high risks, especially as compared with its alternatives, outweigh the minor benefits of use and proposes cancellation.

11. Other Sites

Carbofuran is also registered for use on sites that were not examined with the same degree of intensity. The risks from use on these sites is anticipated to be similar to the risks from the use on the other sites discussed in this document. As previously stated, exposure is often comparable among sites, and bird kills associated with one site strongly suggests that kills also will be associated with similar sites.

EPA has no documentation of bird kills on these sites. However, the lack of documented bird kills associated with a particular use site does not suggest that there are no kills associated with the use of carbofuran have occurred on the use site.

A review of the potential alternatives for these sites indicated that registered alternatives are available for most of the site/pest combinations with the following exceptions:

<u>Site</u>	<u>Pest</u>
<u>Section 3 registrations</u>	
Banana	Weevils
Sugarcane stubble	Wireworms (FL only)
<u>24(c) registrations</u>	
Sugarcane	Sugarcane beetle
Sugarcane stubble	White grubs (TX,1978), Sugarcane beetle (MS,1981)
Sweet corn	Corn stalk weevil (FL,1982)
Alfalfa	Pillbug (IL,1983)
White pine	White pine cone beetle (OH,1983)

EPA did not receive comments during the PD 1 comment period regarding the benefits of use on these sites. Therefore, EPA assumes the benefits are negligible, although no alternatives are registered, and proposes cancellation.

A review of the potential alternatives of the other crops indicated that alternatives that may be used either at-planting or as foliar treatments are available. EPA has determined that the risk outweighs the minor benefits and proposes cancellation of these remaining minor uses of carbofuran.

D. Summary of Proposed Decision

EPA has determined that the risks associated with the use of granular carbofuran outweigh the benefits for each use site. Therefore, EPA proposes that use of carbofuran be cancelled to prevent unreasonable adverse effects. Recognizing that there are substantial risks and substantial benefits associated with carbofuran's use on rice to control the rice water weevil, the Agency is specifically requesting additional information on the risks, use, benefits and other means of control.

The cancellation of granular carbofuran would eliminate the risk by eliminating exposure. If carbofuran is not available for treatment of the 10 crops, the Agency estimated an annual grower impact that ranged from \$22.8 to \$33.0 million. The largest economic impact from cancellation of granular carbofuran will be on rice since no registered alternatives are available for control of the rice water weevil. The Agency estimated a grower impact of \$12.2 million annually; a \$6.1 million decrease in Federal deficiency payments to rice growers would indicate an efficiency loss of \$6.1 million.

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Appendix 1

List of Common and Scientific Names of Birds

Common Name

Scientific Name

Aleutian Canada goose
American bittern
American coot
American goldfinch
American robin
Aplomado falcon
Attwater's greater prairie
chicken

Branta canadensis leucopareia
Botaurus lentiginosus
Fulica americana
Spinus tristis
Turdus migratorius
Falco femoralis
Tympanuchus cupido attwateri

Bachman's sparrow
Baird's sparrow
Bald eagle
Barn owl
Barred owl
Bell's vireo
Black duck
Black rail
Black tern
Black vulture
Blue grosbeak
Blue jay
Blue-winged teal
Boat-tailed grackle
Bobolink
Brant
Brewer's blackbird
Broad-winged hawk
Brown thrasher
Brown-headed cowbird
Burrowing owl

Aimophila aestivalis
Ammodramus bairdii
Haliaeetus leucocephalus
Tyto alba
Strix varia
Verio bellii
Anas rubripes
Laterallus jamaicensis
Chlidonias niger
Coragyps atratus
Guiraca caerulea
Cyanocitta cristata
Anas discors
Quiscalus major
Dolichonyx oryzivorus
Branta bernicla
Euphagus cyanocephalus
Buteo platypterus
Toxostoma rufum
Molothrus ater
Athene cunicularia

California quail
Canada goose
Canvasback
Cardinal
Cinnamon teal
Common grackle
Common crow
Common loon
Common raven
Cooper's hawk
Coturnix quail

Lophortyx californicus
Branta canadensis
Aythya valisineria
Richmondia cardinalis
Anas cyanoptera
Quiscalus quiscula
Corvus brachyrhynchos
Gavia immer
Corvus corax
Accipiter cooperii
Coturnix coturnix

Appendix 1

List of Common and Scientific Names of Birds (Cont'd)

<u>Common Name</u>	<u>Scientific Name</u>
Eastern meadowlark	<u>Sturnella magna</u>
Eastern screech owl	<u>Otus asio</u>
European starling	<u>Sturnus vulgaris</u>
Ferruginous hawk	<u>Buteo regalis</u>
Field sparrow	<u>Spizella pusilla</u>
Fish crow	<u>Corvus ossifragus</u>
Fulvous whistling-duck	<u>Dendrocygna bicolor</u>
Gadwall	<u>Anas strepera</u>
Glossy ibis	<u>Plegadis falcinellus</u>
Golden eagle	<u>Aquila chrysaetos</u>
Golden-cheeked warbler	<u>Dendroica virens</u>
Grasshopper sparrow	<u>Ammodramus savannarum</u>
Great blue heron	<u>Ardea herodias</u>
Great grey owl	<u>Strix nebulosa</u>
Great horned owl	<u>Bubo virginianus</u>
Green-winged teal	<u>Anas carolinensis</u>
Ground dove	<u>Columbigallina passerina</u>
Gull-billed tern	<u>Gelochelidon nilotica</u>
Harris' hawk	<u>Parabuteo unicinctus</u>
Harris' sparrow	<u>Zonotrichia querula</u>
Henslow's sparrow	<u>Passerherbulus henslowii</u>
Horned lark	<u>Eremophila alpestris</u>
House sparrow	<u>Passer domesticus</u>
Hungarian partridge	<u>Perdix perdix</u>
Indigo bunting	<u>Passerina cyanea</u>
Japanese quail	<u>Coturnix coturnix japonica</u>
Kestrel	<u>Falco sparverius</u>
Killdeer	<u>Charadrius vociferus</u>
Lapland longspur	<u>Calcarius lapponicus</u>
Lark bunting	<u>Calamospiza melanocorys</u>
Lark sparrow	<u>Chondestes grammacus</u>
Laughing gull	<u>Larus atricilla</u>
Least bittern	<u>Ixobrychus exilis</u>
Least tern	<u>Sterna albifrons</u>
LeConte's sparrow	<u>Passerherbulus caudacutus</u>
Lincoln's sparrow	<u>Melospiza lincolni</u>
Little blue heron	<u>Florida caerulea</u>
Loggerhead shrike	<u>Lanius ludovicianus</u>

Appendix 1

List of Common and Scientific Names of Birds (Cont'd)

<u>Common Name</u>	<u>Scientific Name</u>
Long-billed curlew	<u>Numenius americanus</u>
Long-eared owl	<u>Asio otus</u>
Mallard	<u>Anas platyrhynchos</u>
Mississippi kite	<u>Ictinia mississippiensis</u>
Mississippi sandhill crane	<u>Grus canadensis</u>
Mockingbird	<u>Mimus polyglottos</u>
Mottled duck	<u>Anas fulvigula</u>
Mountain quail	<u>Oreortyx pictus</u>
Mourning dove	<u>Zenaidura macroura</u>
Northern bobwhite	<u>Colinus virginianus</u>
Northern flicker	<u>Colaptes auratus</u>
Northern harrier (marsh hawk)	<u>Circus cyaneus</u>
Northern shoveler	<u>Spatula clypeata</u>
Northern shrike	<u>Lanius excubitor</u>
Painted bunting	<u>Passerina ciris</u>
Pectoral sandpiper	<u>Erolia melanotos</u>
Peregrine falcon	<u>Falco peregrinus</u>
Pintail duck	<u>Anas acuta</u>
Piping plover	<u>Charadrius melodus</u>
Purple gallinule	<u>Porphyryla martinica</u>
Purple grackle	<u>Quiscalus quiscula</u>
Pyrrhuloxia	<u>Pyrrhuloxia sinuata</u>
Quelea	<u>Quelea quelea</u>
Red cockaded woodpecker	<u>Dendrocopos borealis</u>
Red-bellied woodpecker	<u>Centurus carolinus</u>
Red-headed woodpecker	<u>Melanerpes erythrocephalus</u>
Red-shouldered hawk	<u>Buteo lineatus</u>
Red-tailed hawk	<u>Buteo jamaicensis</u>
Red-winged blackbird	<u>Agelaius phoeniceus</u>
Reddish egret	<u>Dichromanassa rufescens</u>
Ring-necked duck	<u>Aythya collaris</u>
Ring-necked pheasant	<u>Phasianus colchicus</u>
Rock dove	<u>Columba livia</u>
Rose-breasted grosbeak	<u>Pheucticus ludovicianus</u>
Roseate tern	<u>Sterna dougallii</u>
Rough-legged hawk	<u>Buteo lagopus</u>
Ruffed grouse	<u>Bonasa umbellus</u>
Rufous-sided towhee	<u>Pipilo erythrophthalmus</u>
Rusty blackbird	<u>Euphagus carolinus</u>

Appendix 1

List of Common and Scientific Names of Birds (Cont'd)

<u>Common Name</u>	<u>Scientific Name</u>
Sandhill crane	<u>Grus canadensis</u>
Savannah sparrow	<u>Passerculus sandwichensis</u>
Saw-whet owl	<u>Aegolius acadicus</u>
Scoter	<u>Oidemia nigra</u>
Screech owl	<u>Otus asio</u>
Scrub jay	<u>Aphelocoma coerulescens</u>
Semipalmated sandpiper	<u>Ereunetes pusillus</u>
Sharp-shinned hawk	<u>Accipiter striatus</u>
Sharp-tailed grouse	<u>Pedioecetes phasianellus</u>
Short-eared owl	<u>Asio flammeus</u>
Snipe	<u>Capella gallinago</u>
Snowy egret	<u>Leucophoyx thula</u>
Snowy plover	<u>Charadrius alexandrinus</u>
Song sparrow	<u>Melospiza melodia</u>
Sora	<u>Porzana carolina</u>
Spotted owl	<u>Strix occidentalis</u>
Spotted sandpiper	<u>Actitis macularia</u>
Stilt sandpiper	<u>Micropalama himantopus</u>
Swainson's hawk	<u>Buteo swainsoni</u>
Tricolored heron	<u>Hydranassa tricolor</u>
Tri-colored blackbird	<u>Agelaius tricolor</u>
Trumpeter swan	<u>Olor buccinator</u>
Tufted titmouse	<u>Parus bicolor</u>
Upland plover	<u>Bartramia longicauda</u>
Vesper sparrow	<u>Pooecetes gramineus</u>
Western meadowlark	<u>Sturnella neglecta</u>
Whip-poor-will	<u>Caprimulgus vociferus</u>
White ibis	<u>Eudocimus albus</u>
White-breasted nuthatch	<u>Sitta carolinesis</u>
White-faced ibis	<u>Plegadis chihi</u>
White-necked raven	<u>Corvus cryptoleucus</u>
White-throated sparrow	<u>Zonotrichia albicollis</u>
White-winged dove	<u>Zenaida asiatica</u>
Whooping crane	<u>Grus americana</u>
Widgeon	<u>Mareca americana</u>
Wild turkey	<u>Meleagris gallopavo</u>

Appendix 1

List of Common and Scientific Names of Birds (Cont'd)

Common Name

Scientific Name

Wood duck

Aix sponsa

Woodcock

Philohela minor

Yellow-headed Blackbird

Xanthocephalus xanthocephalus

Appendix 2

Summary of Carbofuran Residue Levels (ppm) and the Number of Granules Found in Each Bird in Field Study 1

<u>Species</u>	<u>Residue Level (ppm)</u>	<u>Number of Granules</u>
Horned lark	853.2	30
	598.4	53
	403.0	14
	339.7	20
	335.6	19
	301.8	32
	277.0	8
	247.7	10
	210.9	23
	207.6	8
	189.1	8
	174.2	24
	166.1	16
	139.0	2
	137.4	4
	129.9	4
	123.8	6
	120.2	1
	119.6	4
	115.9	11
	104.6	9
	97.4	6
	86.8	8
	80.8	4
	72.5	0
	69.9	5
	69.2	10
	67.4	7
	64.6	2
	61.6	4
	61.3	9
	59.4	9
	59.2	2
	58.8	5
	57.9	9
	56.6	3
	55.8	3
	55.7	7
	52.1	0
	47.9	4
	46.0	4
	40.1	1
	37.9	6

Appendix 2

Summary of Carbofuran Residue Levels (ppm) and the Number of Granules Found in Each Bird in Field Study 1 (cont'd)

<u>Species</u>	<u>Residue Level (ppm)</u>	<u>Number of Granules</u>
Horned lark (cont'd)	36.5	3
	32.2	2
	31.6	6
	31.1	2
	30.3	2
	29.1	2
	28.7	3
	28.1	32
	23.5	1
	22.3	0
	22.0	2
	21.3	2
	17.3	4
	15.8	2
	15.5	2
	15.5	0
	14.6	3
	14.2	2
	12.2	2
	11.2	1
	10.0	1
	9.5	2
	9.3	1
	9.0	1
	8.5	2
	5.9	1
	5.7	5
	5.5	1
	5.5	0
	5.4	1
	4.8	2
	4.7	2
	4.6	1
	4.5	0
	4.3	1
	4.2	1
	3.4	0
	3.3	1
	3.1	0
	2.6	2
	2.5	2
	2.4	5
	2.4	0
	2.3	4
	2.2	2

Appendix 2

Summary of Carbofuran Residue Levels (ppm) and the Number of Granules Found in Each Bird in Field Study 1 (cont'd)

<u>Species</u>	<u>Residue Level (ppm)</u>	<u>Number of Granules</u>
Horned lark (cont'd)	2.0	1
	1.8	2
	1.7	1
	1.5	1
	1.4	0
	1.3	0
	0.7	0
	0.7	0
	0.6	0
	0.4	0
	0.2	0
	0.0	0
	0.0	0
	0.0	1
	0.0	1
	0.0	3
	0.0	1
No intestinal tract		
Yellow-headed blackbird	155.3	6
	33.9	5
	24.5	2
	19.8	1
	18.1	3
	17.6	2
	14.4	0
	8.7	2
	8.1	0
	7.0	1
	4.6	0
	0.0	0
	0.0	0
	0.0	0
	0.0	0
Brown-headed cowbird	19.6	1
	14.0	5
	1.8	5
	1.4	0
	0.9	1
	0.6	0
	0.5	0
	0.0	2
	0.0	1
	0.0	0
	0.0	0
	0.0	8
	0.0	2
	0.0	7
Sample lost in extraction		0

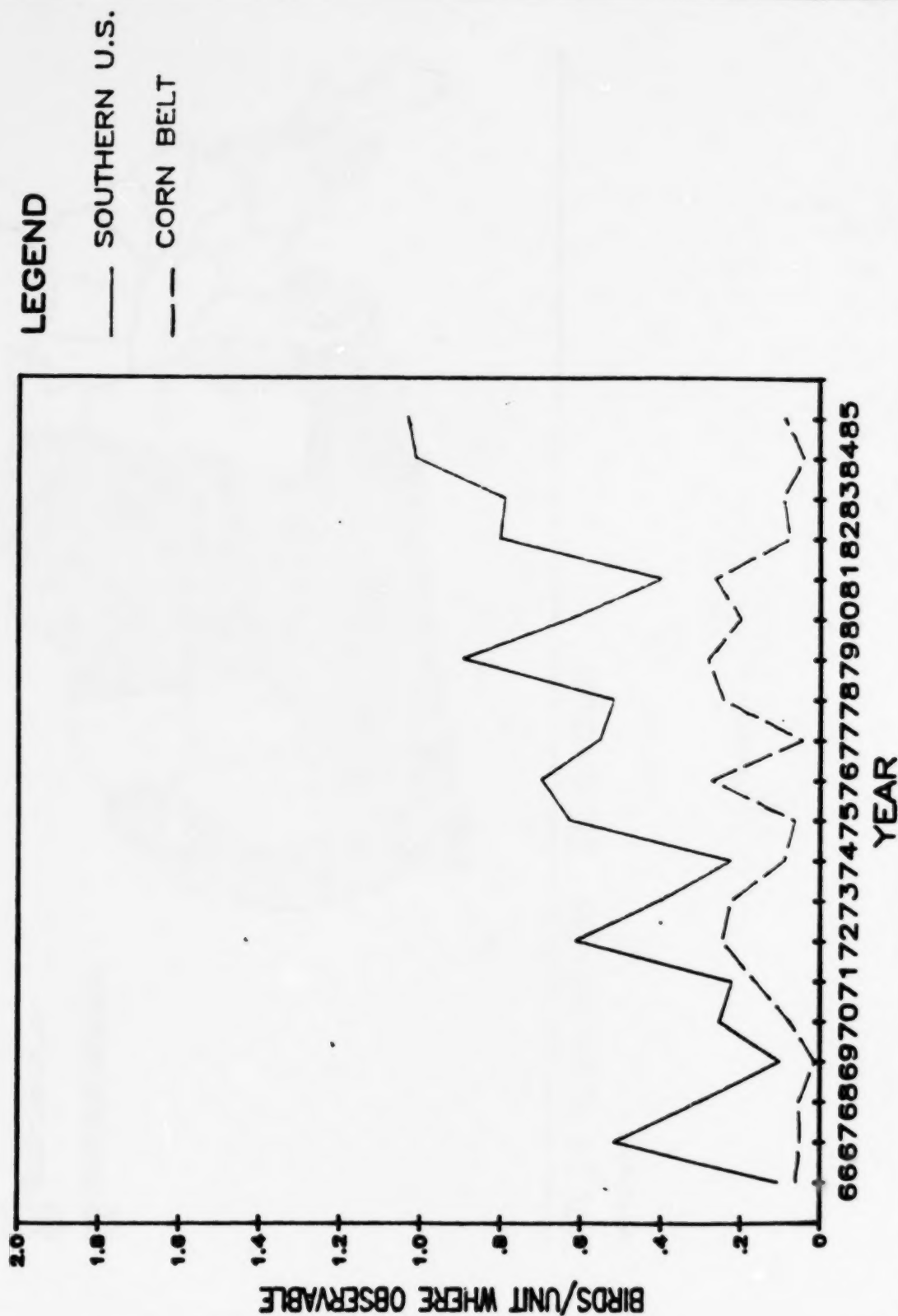
Appendix 2

Summary of Carbofuran Residue Levels (ppm) and the Number of Granules Found in Each Bird in Field Study 1 (cont'd)

<u>Species</u>	<u>Residue Level (ppm)</u>	<u>Number of Granules</u>
Mourning dove	81.2	7
	62.8	3
	13.5	3
	7.6	3
	6.9	0
	4.8	1
Raven	8.1	38
	6.6	16
Northern harrier	21.8	23
Ring-necked pheasant	63.6	23

Appendix 3

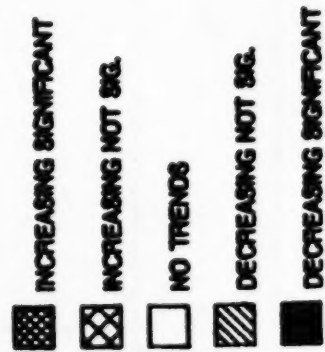
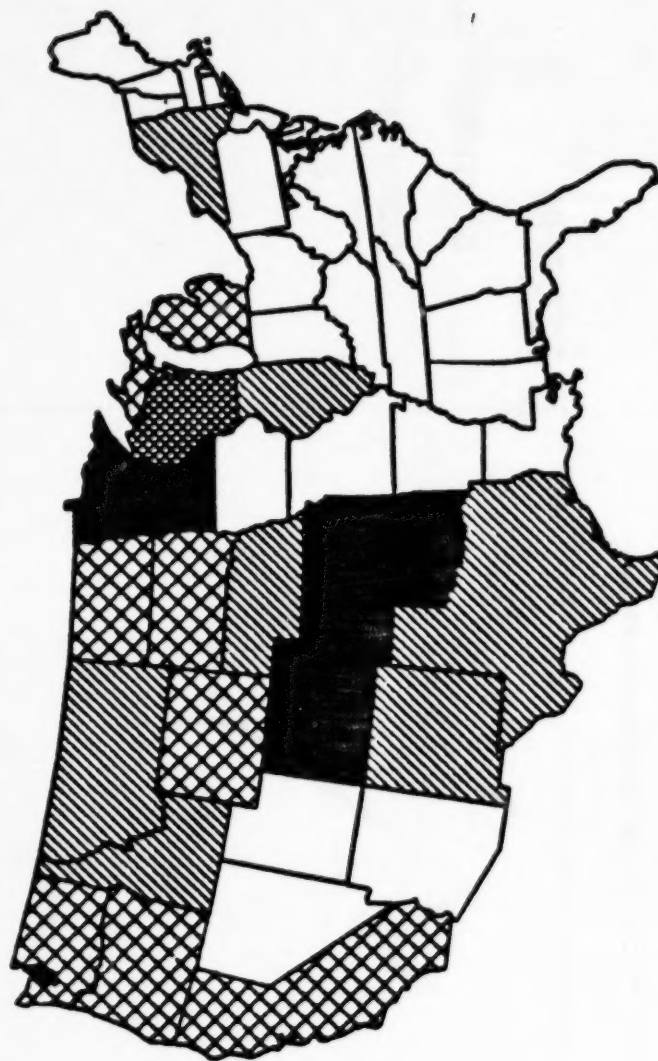
Population Trends of the Red-shouldered Hawk



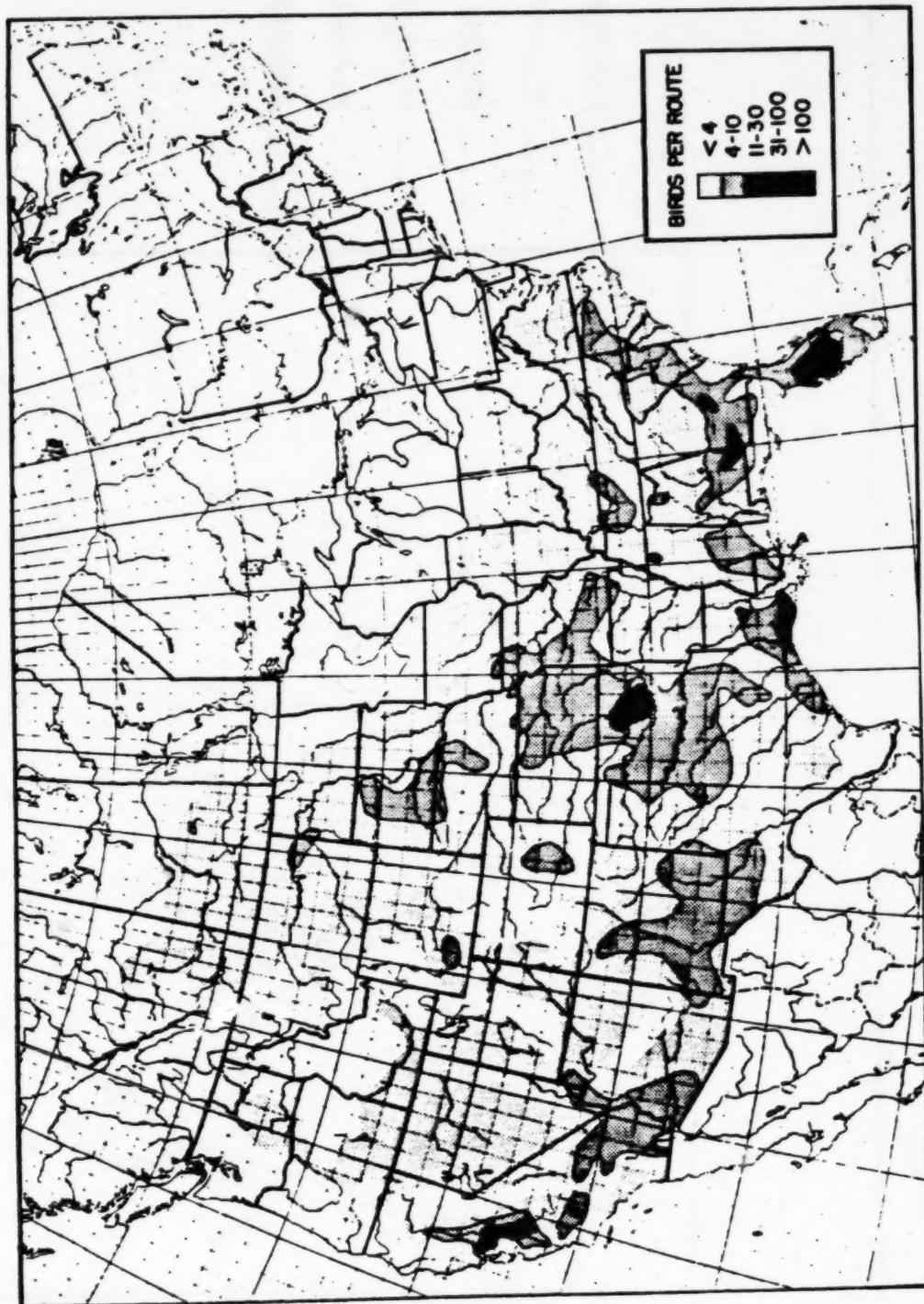
Appendix 4

Marsh Hawk

BBS 20 YEAR TRENDS SIG ($P < 0.05$)



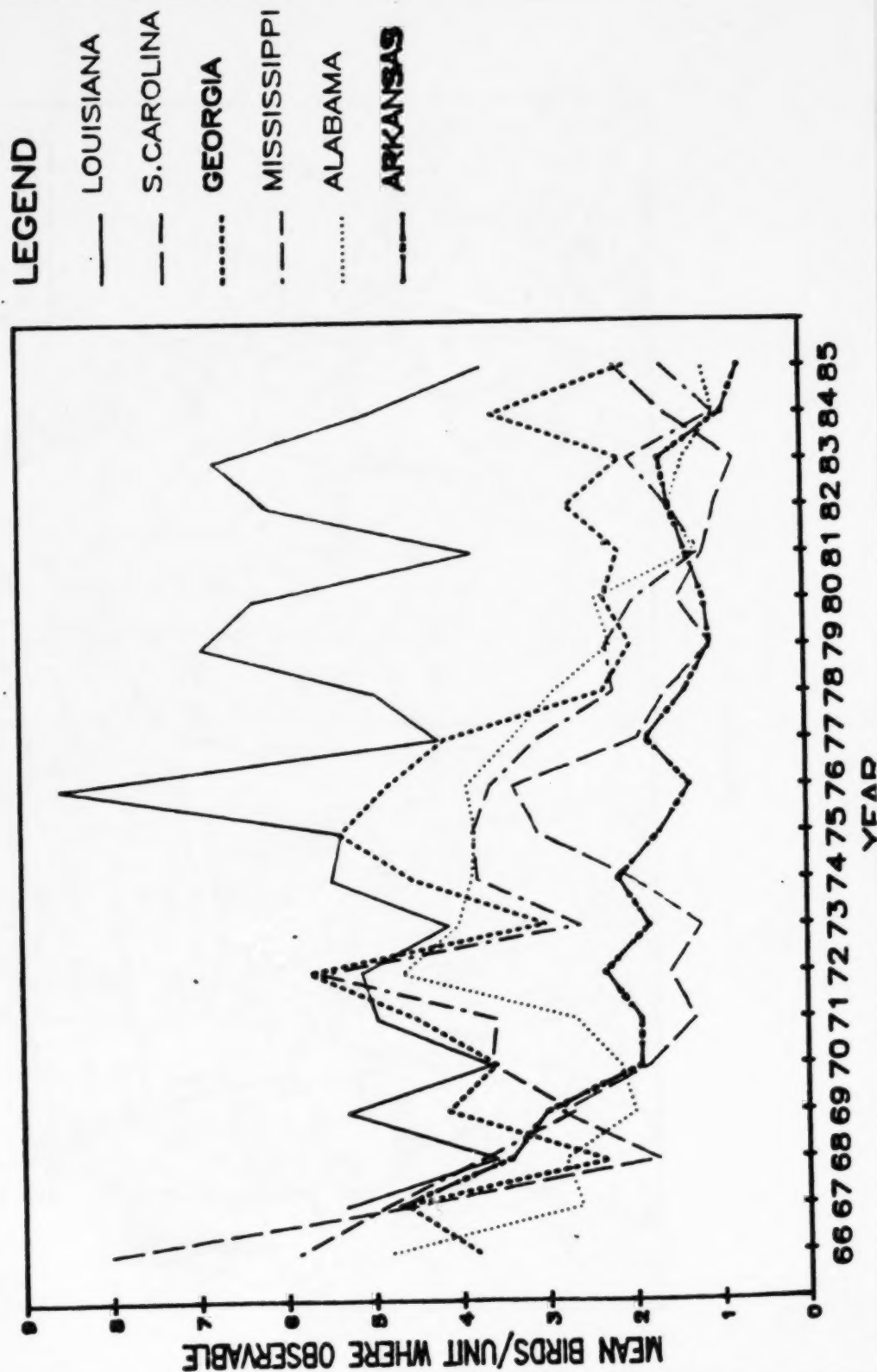
Appendix 5



Mean relative abundance of Loggerhead Shrike
(1966-1980) (Robbins et al. 1986)

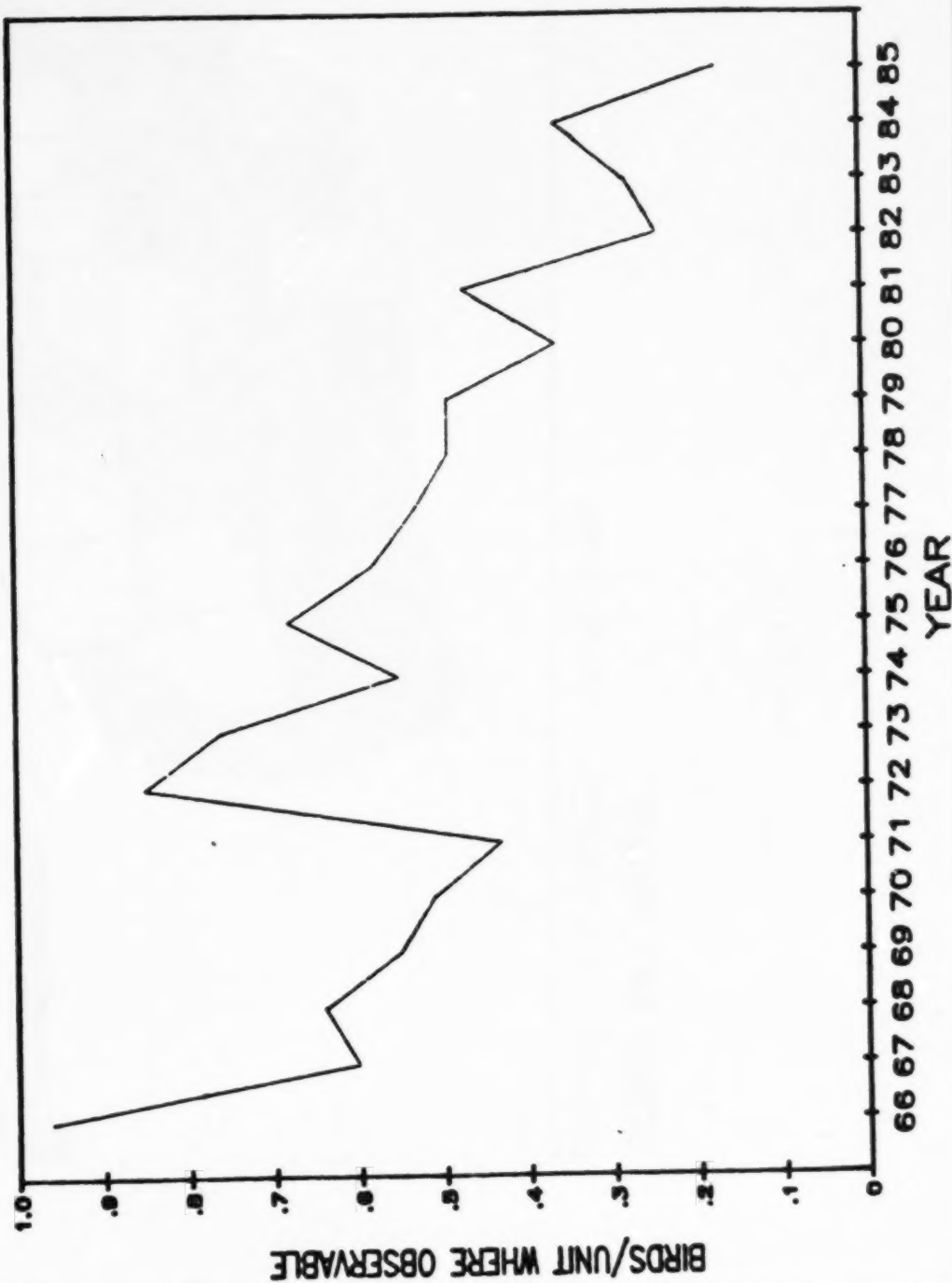
Appendix 6

Population Trends of the
Loggerhead Shrike in the
Southern United States



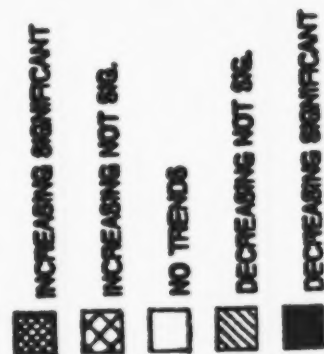
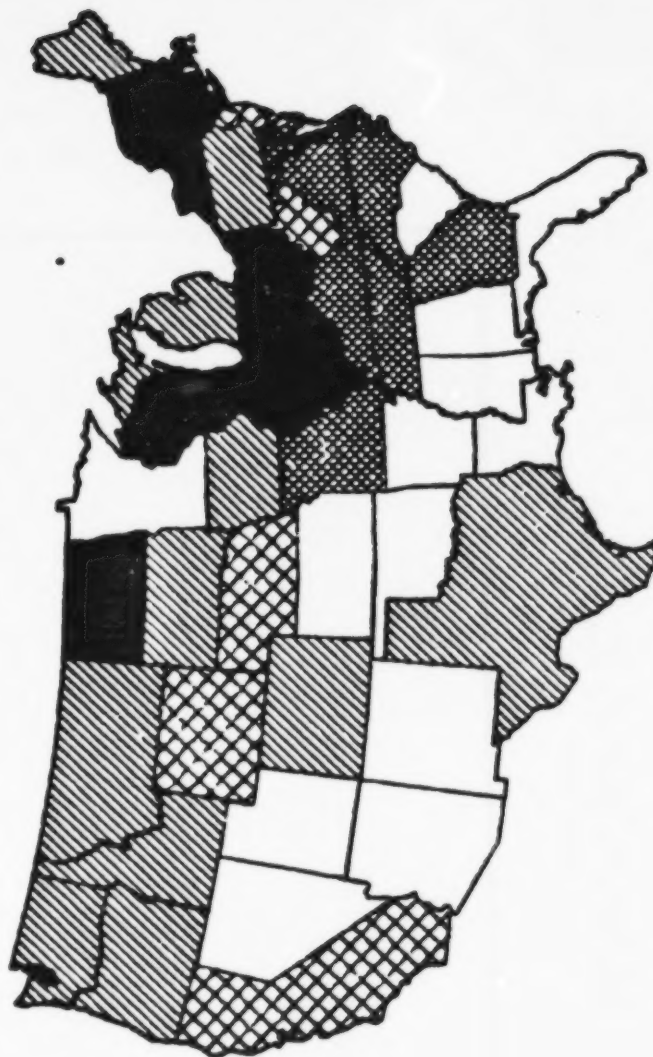
Appendix 7

Population Trends of the Henslow's Sparrow in the Corn Belt



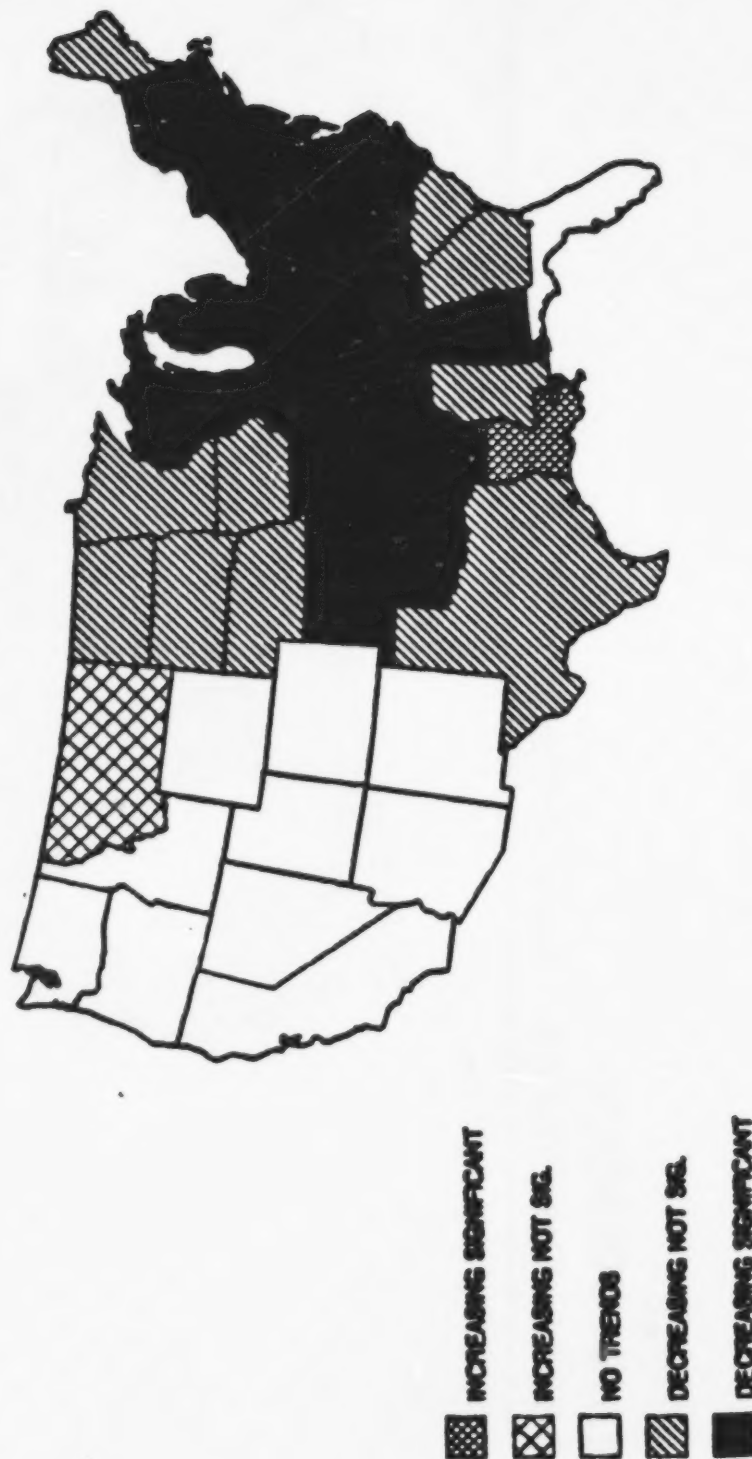
SONG SPARROW

BBS 20 YEAR TRENDS SIG ($P < 0.05$)



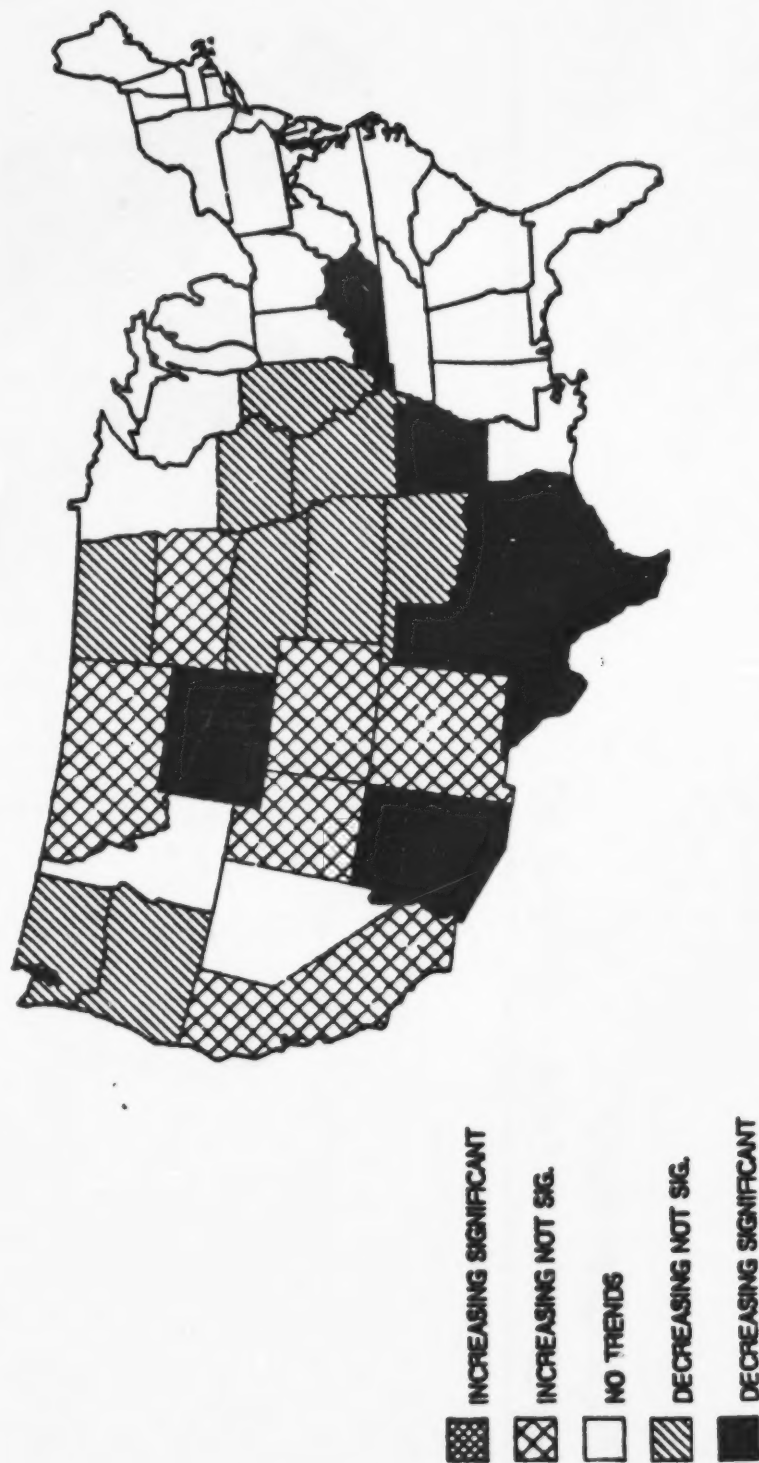
FIELD SPARROW

BBS 20 YEAR TRENDS SIG ($P < 0.05$)



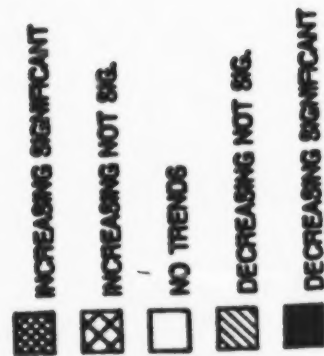
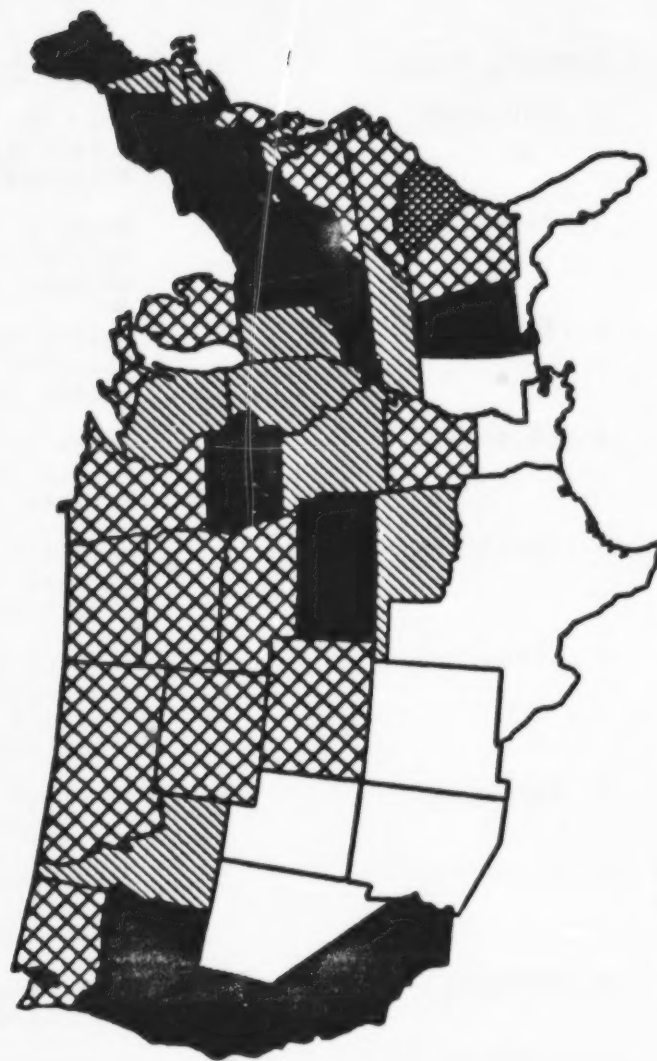
LARK SPARROW

BBS 20 YEAR TRENDS SIG ($P < 0.05$)



AMERICAN GOLDFINCH

BBS 20 YEAR TRENDS SIG ($P < 0.05$)



Provided by the Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service

Appendix 12

Public Comments Submitted for the
Carbofuran Special Review

<u>Comment Number</u>	<u>Author/Affiliation</u>
1 (30000/48)	Carl H. Shanks, Jr. Superintendent and Entomologist Washington State University
2 (30000/48)	Richard C. Maxwell Agricultural Chemicals Specialist Washington State University
3 (30000/48)	Catherine A. Sazdanoff Attorney Abbott Laboratories
4 (30000/48)	Chuck Pace Pesticide Associate National Audubon Society
5 (30000/48)	Melvin D. Androus Manager Rice Research Board
6 (30000/48)	Pauline D. Plaza Chairperson Wildlife Subcommittee Denver Audubon Society
7 (30000/48)	David Pincus FMC Corporation
8 (30000/48)	Harvey V. Toko Director of Forest Pest Management USDA, Forest Service
9 (30000/48)	Diane Heminway Medina, New York
10 (30000/48)	Ward B. Stone Associate Wildlife Pathologist New York State Department of Environmental Conservation

Appendix 12

Public Comments Submitted for the Carbofuran
Special Review (cont'd)

<u>Comment Number</u>	<u>Author/Affiliation</u>
11 (30000/48)	Harold G. Alford Regional Coordinator University of California
12 (30000/48)	Summary of a meeting with representatives of FMC Corporation; not a public comment
13 (30000/48)	Melvin D. Androus Manager Rice Research Board

Appendix 13

List of Common and Scientific Names of Insects and Nematodes

<u>Common Name</u>	<u>Scientific Name</u>
<u>Insects</u>	
Armyworm	<u>Pseudaletia unipuncta</u> , <u>Spodoptera frugiperda</u>
Bean thrips	<u>Caliothrips faciatu</u> s
Billbugs	<u>Sphenophorus spp.</u>
Black cutworm	<u>Agrotis ipsilon</u>
Black vine weevil	<u>Otiiorhynchus sulcatus</u>
Chinch bug	<u>Blissus leucopterus</u>
Clearwinged grasshopper	<u>Camnula pellucida</u>
Colorado potato beetle	<u>Leptinotarsa decemlineata</u>
Common stalk borer	<u>Papaipema nebris</u>
Cone beetles	<u>Conophthorus spp.</u>
Cone borers	<u>Eucosma spp.</u>
Coneworms	<u>Dioryctria spp.</u>
Corn flea beetle	<u>Chaetocnema pulicaria</u>
Corn rootworm complex	<u>Diabrotica spp.</u>
Cotton thrips	<u>Frankliniella fusca</u>
Dark ricefield mosquito	<u>Psorophora columbiae</u>
Differential grasshopper	<u>Melanoplus differentialis</u>
European corn borer	<u>Ostrinia nubilalis</u>
Greenbug	<u>Schizaphis graminum</u>
Green peach aphid	<u>Myzus persicae</u>
Leaffooted pine seedbug	<u>Leptoglossus corculus</u>
Leafhopper	(<u>Cicadellidae</u>)
Mexican bean beetle	<u>Epilachna varivestis</u>
Migratory grasshopper	<u>Melanoplus sanguinipes</u>
Nantucket pine tip moth	<u>Rhyacionia frustrana</u>
Northern corn rootworm	<u>Diabrotica barberi</u>
Onion thrips	<u>Thrips tabaci</u>
Pales weevil	<u>Hylobius pales</u>
Pitch-eating weevil	<u>Pachylobius picivorus</u>
Pitch pine tip moth	<u>Rhyacionia rigidana</u>
Potato leafhopper	<u>Empoasca fabae</u>

Appendix 13

List of Common and Scientific Names of Insects and Nematodes (cont'd)

<u>Common Name</u>	<u>Scientific Name</u>
Redlegged grasshopper	<u>Melanoplus fermurrubrum</u>
Rice water weevil	<u>Lissorhoptrus oryzophilus</u>
Seed corn maggot	<u>Hylemya platura</u>
Shieldback pine seedbug	<u>Tetyra bipunctata</u>
Southern corn billbug	<u>Sphenophorus callosus</u>
Southern corn rootworm	<u>Diabrotica undecimpunctata howardi</u>
Southern cornstalk borer	<u>Diatraea crambidoides</u>
Southwestern corn borer	<u>Diatraea graniosella</u>
Soybean thrips	<u>Sericothrips variabilis</u>
Spotted cucumber beetle	<u>Diabrotica undecimpunctata howardi</u>
Sunflower beetle	<u>Zygogramma exclamationis</u>
Sunflower stem weevil	<u>Cylindrocopturus adspersus</u>
Tobacco budworm	<u>Heliothis virescens</u>
Tobacco flea beetle	<u>Epitrix hirtipennis</u>
Tobacco hornworm	<u>Manduca sexta</u>
Tomato hornworm	<u>Manduca quinquemaculata</u>
Twostriped grasshopper	<u>Melanoplus bivittatus</u>
Western corn rootworm .	<u>Diabrotica virgifera</u>
Western flower thrips	<u>Frankliniella occidentalis</u>
White grubs	<u>Phyllophaga spp.</u>
Wireworms	(Elateridae)
<u>Nematodes/Site</u>	
Cyst/soybean	<u>Heterodera spp.</u>
Dagger/corn	<u>Xiphenema spp.</u>
Lance/corn	<u>Hoplolaimus spp.</u>
Lesion/corn, peanuts	<u>Pratylenchus spp.</u>
Ring/peanuts	<u>Criconemoides spp.</u>
Root-knot/corn, peanuts, tobacco	<u>Meloidogyne spp.</u>
Spiral/corn	<u>Helicotylenchus spp.</u>
Sting/corn, peanuts	<u>Belonolaimus spp.</u>
Stubby root/corn	<u>Trichodorus spp.</u>
Stunt/corn, peanuts, tobacco	<u>Tylenchorhynchus spp.</u>

Appendix 14

Statistical Analysis for Insecticide Treatments in Field Corn¹

State	Chemical ²	Number of Replicates	Yield (Mean) ³	Standard Deviation	Normality ⁴	Probability (0.01)
IA	PH15	3	136.63 a	50.67	W:893771	0.347
IA	CA10	7	128.34 a	29.38	W:0.990486	1.00
IA	ET10	4	128.26 a	16.97	W:0.946668	0.59
IA	FO20	7	125.77 a	30.78	W:0.944151	0.647
IA	TE15	7	125.29 a	28.51	W:0.920774	0.468
IA	ET15	6	123.94 a	30.93	W:0.947369	0.673
IA	CH20	7	122.01 a	32.21	W:0.95015	0.701
IA	PH20	5	119.13 a	19.32	W:0.856135	0.266
IL	ETH	4	164.89 a	15.21	W:0.892025	0.38
IL	FO20	6	159.81 ab	25.10	W:0.89462	0.372
IL	CA10	15	144.72 abc	19.69	W:0.963707	0.719
IL	TE15	11	142.11 bc	16.85	W:0.949976	0.621
IL	CH20	12	137.92 c	16.24	W:0.971456	0.879
IN	PH20	3	139.02 a	10.82	W:0.973684	0.651
IN	FO20	3	136.40 a	12.87	W:0.981459	0.73
IN	CH20	3	135.44 a	11.14	W:0.999974	0.979
IN	TE15	3	134.23 a	16.17	W:930431	0.433
IN	CA10	3	128.23 a	18.65	W:0.855297	0.256
MN	CH20	4	149.00 a	38.26	W:0.913653	0.44
MN	CA15	6	144.77 a	25.11	W:0.921707	0.479
MN	TE15	6	141.00 a	28.43	W:0919264	0.469
MN	ET15	5	140.46 a	29.38	W:0.926583	0.499
MN	FO20	5	140.38 a	26.76	W:0.90262	0.419
MN	PH20	5	138.44 a	26.09	W:0.964858	0.791
NE	CH20	10	143.21 a	26.01	W:0.959867	0.757
NE	PH15	12	142.45 a	25.47	W10.881166	0.096
NE	D14G	10	142.13 a	30.13	W:0.916266	0.374
NE	ET15	8	140.87 a	31.79	W:0.953234	0.712
NE	CA10	23	137.98 a	30.10	W:0.950217	0.361
NE	PH20	9	137.41 a	21.41	W:0.937656	0.529
NE	CA15	7	135.82 a	34.04	W:0.918087	0.456
NE	TE15	23	135.51 a	30.87	W:0.986019	0.97
NE	FE15	8	134.96 a	30.68	W:0.924944	0.465
NE	FO20	19	129.87 a	29.58	W:0.963833	0.63
NE	ET10	3	121.43 a	7.43	W:0.963413	0.545

Appendix 14

Statistical Analysis for Insecticide Treatments in Field Corn¹ (cont'd)

State	Chemical ²	Number of Replicates	Yield (Mean) ³	Standard Deviation	Normality ⁴	Probability (0.01)
OH	CA10	3	160.00 a	15.0	W:0.841121	0.223
OH	TE15	3	155.10 a	22.38	W:0.949569	0.478
WY	CA10	4	156.18 a	11.25	W:0.954658	0.651
WY	TE15	6	154.18 a	10.75	W:0.992964	1
WY	FO20	4	152.08 a	14.90	W:0.880112	0.346
WY	TE20	4	151.93 a	18.18	W:0.916690	0.449
WY	CA15	6	149.60 a	7.47	W:0.920361	0.474
WY	PH20	4	148.03 a	11.35	W:0.797223	0.115
IA	ET15	4	130.05 a	34.34	W:0.919067	0.455
IA	FO20	15	117.26 a	41.81	W:0.950286	0.505
IA	TE15	20	115.00 a	42.49	W:0.912603	0.075
IA	CA10	18	114.38 a	38.96	W:0.941032	0.357
IA	ET10	15	110.91 a	38.44	W:0.880361	0.049
IA	FO15	3	108.23 a	45.88	W:0.841878	0.224
IA	CH20	16	108.21 a	43.42	W:0.948510	0.47
IA	PH15	16	107.39 a	44.09	W:0.962425	0.674
IA	CA15	3	102.20 a	41.18	W:0.885354	0.327
IA	TR10	3	95.60 a	42.78	W:0.982133	0.737
IA	FE15	4	92.47 a	57.92	W:0.855738	0.278
IL	TE15	13	132.34 a	17.29	W:0.838711	0.022
IL	CH20	13	131.92 a	17.62	W:0.910744	0.255
IL	CA15	14	126.67 a	18.62	W:0.863204	0.038
IL	ET15	3	115.13 a	17.03	W:0.760084	0.031
IL	TR15	3	113.20 a	16.91	W:0.929065	0.43
IL	PH20	3	111.80 a	18.65	W:0.900319	0.362
IN	PH20	17	144.13 a	18.37	W:0.938555	0.360
IN	FO20	20	134.82 a	32.65	W:0.896660	0.038
IN	CA15	28	127.33 a	38.83	W:0.906414	0.019
IN	CH20	24	125.79 a	41.50	W:0.915439	0.049
IN	ET15	14	125.73 a	36.47	W:0.874876	0.052
IN	TE15	27	125.70 a	39.89	W:0.931967	0.087
IN	TR15	13	119.69 a	38.38	W:0.923422	0.346
NE	ET15	10	128.09 a	27.96	W:0.970236	0.879
NE	PH20	13	124.46 a	27.08	W:0.910410	0.253
NE	D14G	9	123.53 a	35.07	W:0.923750	0.441
NE	CH20	11	122.94 a	33.89	W:0.945076	0.562
NE	CA10	13	121.92 a	26.41	W:0.943714	0.491
NE	TE15	21	118.50 a	33.46	W:0.931614	0.193

Appendix 14

Statistical Analysis for Insecticide Treatments in Field Corn¹ (cont'd)

State	Chemical ²	Number of Replicates	Yield (Mean) ³	Standard Deviation	Normality ⁴	Probability (0.01)
NE	TR15	4	115.78 a	15.77	W:0.896131	0.391
NE	FE15	4	114.78 a	38.05	W:0.994327	0.967
NE	FO20	20	113.58 a	30.66	W:0.946736	0.374
NE	CA15	11	112.29 a	31.13	W:0.938370	0.049

¹ References are summarized at the end of this analysis.

² PH15 = Phorate 15G
 CA10 = Carbofuran 10G
 ET10 = Ethoprop 10G
 FO20 = Fonofos 20 G
 TE15 = Terbufos 15G
 ET15 = Ethoprop 15G
 CH20 = Chlorpyrifos 15G
 PH20 = Phorate 20G
 ETH = Ethion 10G
 CA15 = Carbofuran 15G
 DI4G = Diazinon 14G
 TE20 = Terbufos 20G
 TR10 = Trimethacarb 10G
 FE15 = Fensulfothion 15G
 TR15 = Trimethacarb 15G

³ All means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan Multiple range test.

⁴ Shapiro-Wilk Test for normality.

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